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COSMOS:

SKETCH

OF A

PHYSICAL DESCRIPTION OF THE UNIVERSE.

BY

ALEXANDER VON HUMBOLDT.

VOL. IV.—PART I.

Naturæ vero rerum vis atque majestas in omnibus momentis fide caret, si quis modo partes ejus ac non totam complectatur animo.—PLIN. H. N. lib. vii. c. 1.

TRANSLATED UNDER THE SUPERINTENDENCE OF

MAJOR-GENERAL EDWARD SABINE, R.A., D.C.L.

V.P. AND TREAS. R.S.

CHEVALIER OF THE ROYAL PRUSSIAN ORDER "*pour le mérite*" IN SCIENCE.

LONDON:

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1858.

EDITOR'S PREFACE.

As may be seen in page xxii. of the English translation of the author's preface to vol. i., in p. 8 of vol. ii., and in p. 13 of the present volume, it was the author's intention that the fourth and concluding volume of the "Kosmos" should contain, for the telluric portion of the universe, a notice of the specialities of the several branches of science of which the mutual connection had been indicated in the "general view of nature" presented in the first volume; the specialities of the uranological portion having been treated in volume iii. It has proved impossible, however, to comprise within the limits of an ordinary single volume the treatment of both the "inorganic and organic domains" of terrestrial nature, as contemplated in p. 13 of the present volume, or even the whole of what is there indicated as appertaining to the first of these divisions: the fourth

volume will, therefore, consist of two parts, of which the first was published in the German original at the commencement of the present year, and is now presented in the English translation; the possibility of publishing the work in English within so short a time of its appearance in German being the result of the early possession of the larger portion of the proof sheets, for which advantage the editor and translator are indebted to the good offices of M. de Humboldt himself, and to the obliging permission of the German publisher, Mr. Cotta.

The first 224 pages of the original text and notes were printed early in 1854. The long attachment of the illustrious author to the subject of terrestrial magnetism, which is contained therein, and which in a very large measure owes to him, and to the impulse given by him, the position which it now occupies, rendered him even peculiarly desirous that its treatment should correspond fully to the latest progress of our knowledge. That progress has been such as to render the years which have elapsed since 1854 equivalent to a much longer interval in other departments of science. In this view, therefore, besides making himself some brief but important additions in pp. 449 to 452, M. de Humboldt has expressed, on several occasions in the course of our correspondence, a desire that I should make in

the English translation further rectifications and enlargements, which he might afterwards embody in the work itself, on the completion of its concluding portion.

In compliance with this honourable and gratifying request, I have ventured to make some corrections in pp. 104 to 107 of the original (114 to 117 of the translation), and have added three notes — one on the figure of the earth, and two on subjects in terrestrial magnetism; these will be found in pp. 453 to 516. That in so doing I have not gone beyond either the letter or the spirit of M. de Humboldt's express desire will, I think, best appear by the following extracts from his correspondence, which I therefore permit myself to make: —

"Tout ce qui appartient aux détails des corrections spéciales, comme pp. 113–117, que je possède déjà imprimées en votre traduction, peut être réservé à la nouvelle édition de tout le 'Kosmos' qui sera publiée quelques mois après que le 4^{me} volume, seconde et dernière partie, sera terminé. Tous les changemens que vous daignerez faire dans la traduction actuelle du 4^{me} volume, partie première (et je vous supplie d'en faire beaucoup), seront employés consciencieusement." . . . "Je ferai la plus vive attention à toutes les corrections que vous daignerez ajouter en notes à la traduction, comme aux changemens que vous introduirez immédiatement

dans le texte. Je réserve tout cela pour des *additions* à la fin du vol. iv, seconde et dernière section. C'est là que trouveront leur places les changemens que je découvre dans vos pp. 113–117. Vous sentez, mon cher ami, qu'il sera plus utile de réunir tout ce dont votre traduction aura enrichi l'ouvrage, et de le placer à la fin de l'ouvrage, en traduisant en allemand les passages entiers quelques longs qu'ils puissent être." . . . " Je veux que rien ne se perde pour l'Allemagne de ce qui vient de vous, ayant la prétention de donner dans mon 'Kosmos' vos travaux dans leur grand ensemble, comme ils ne se trouvent encore nulle part."

Some passages which occur in the commencement of the first volume of "Kosmos," relating to the physical sciences generally, and to the manner in which, in different stages of their progress, their results are more or less susceptible of being presented under general points of view, appear to me so appropriate to the past and present state of the science of terrestrial magnetism, that in attempting the following brief explanation of the manner in which I have endeavoured to fulfil the wish conveyed in the preceding extracts, I adopt those expressions in great measure as conveying the views which I entertain, and by which I have been guided. Amongst the many branches into which terrestrial magnetism divides itself, it is only very recently that some

have begun to emerge from that state in which "facts, though studied with assiduity and sagacity, still appear for the most part unconnected, with little mutual relation, and it may be even in some instances in seeming contradiction with each other." I venture to think that these, the most advanced branches of terrestrial magnetism, have already in some measure reached the stage at which "observations having multiplied, and having been combined by reflection, more and more points of contact and links of mutual relation are discovered," and the intricacies arising from the "excessive combination of phænomena" are already yielding to a "knowledge of the primary laws by which they are regulated," which knowledge is, in its turn, conducting to still "higher and more extensive generalisations"—thus preparing the way for that yet more advanced stage, when "a deeper insight into natural forces may be attained." Yet while in regard to these branches it is already becoming "more and more possible to develop general truths with conciseness without superficiality," that task is still one of very great difficulty, and admits of only imperfect and partial realisation. Therefore, inasmuch as it was impossible for me to comprehend within any admissible limits a complete *résumé* of all that has already been gained in terrestrial magnetism, I have, on the present occasion,

written notes on two branches only of the general subject—viz. on the magnetic disturbances, and on the solar diurnal variation of the declination; in respect to these branches "combination, by reasoning, of the aggregation of observed facts," their "generalisation," and the progressive "discovery of laws," have advanced so far that it has become possible, agreeably to the presiding idea of M. de Humboldt's work on the Kosmos, to "arrange the phænomena in such a connection and sequence as may facilitate the insight into their causal connection." To treat these two subjects "without superficiality" has fully engrossed all the space that I could permit myself to occupy, seeing the number of pages to which the present volume has extended.

EDWARD SABINE.

13, Ashley Place, London:
April 14th, 1858.

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INTRODUCTION.

In a work of very extensive scope, in which facility of comprehension and the production of a clear and distinct general impression are especially aimed at, the structure of the work, and the co-ordination and arrangement of the several parts which compose the whole, are almost even more important than the richness and abundance of the materials. This is the more sensibly felt in the "Cosmos," or "Book of Nature," where it is necessary to separate carefully the generalisation of our theme, both in the objective view of external phænomena and in the reflection of nature in the mirror of man's inner being, from the narration of the several results of observation. The first two volumes of my work were devoted to the generalisation thus

spoken of, first in the contemplation of the universe as a natural whole, and next in an endeavour to show how in the course of centuries, at different periods in the history of the human race, and in the most different regions of the earth, mankind had progressively advanced towards a recognition of the concurrent action of the forces of nature. Although the arrangement in a significant order of the descriptions of phænomena is in itself adapted to lead us to recognise their causal connection, yet it could not be hoped that a general representation should appear fresh, animated, and life-like, unless restricted within such limits as should not permit the general effect to be lost, under the excessive and too crowded accumulation of separate facts.

As in collections of geographical or geological maps, representing graphically the configuration of land and sea, or the characters and arrangement of the rocks at the earth's surface, general maps are made to precede special ones; so it has appeared to me most fitting that in the Physical Description of the Universe, its representation as a whole, contemplated from more general and higher points of view, should be followed by the separate presentation, in the two last volumes, of those special results of observation on which the present state of our knowledge is more particularly based. These two last volumes, therefore (as I have already remarked, Bd. iii. S. 4—9; Engl. p. 4—9), are to be regarded simply as an extension and more careful elaboration of the general representation of Nature, which constituted my first volume; and as the third was devoted exclusively to the uranological or sidereal domain of the Cosmos, so the present and last volume is designed to treat of the telluric sphere, or of the phænomena belonging to the globe which we inhabit. We

thus retain the highly ancient, simple, and natural division of creation into the Heavens and the Earth, as preserved to us in the earliest monuments of all nations.

If already, in the course of the last volume, in passing from the consideration of the heaven of the fixed stars—in which countless suns shine either singly, or revolving round each other, or are known to us only as constituting the faint light of distant nebulæ,—we felt the transition to our own planetary system to be a descent from the great and universal to the relatively small and special, the field of contemplation becomes restricted within yet far narrower limits, in passing, as we are now to do, from the totality of the varied solar system to one only of the planets which circle round its central luminary. The distance of the nearest of the fixed stars, α Centauri, is still 263 times greater than the diameter of the solar system taken to the aphelion of the comet of 1680, and yet the latter distance is itself 853 times greater than that of our Earth from the Sun. (Kosmos, Bd. iii. S. 582; Engl. p. 261). These numbers (in which the parallax of α Centauri is taken at $0''{\cdot}9187$) assign approximately the distance of a comparatively near region of sidereal space from the conjectured outermost limit of the solar system, and the distance of this latter limit from the Earth.

Uranology, which occupies itself with the contents of the remote regions of space, still preserves its ancient prerogative of affecting the imagination by the most powerful impressions of the sublime, the inconceivable vastness of the relations of space and number which it presents, the recognised order and law which govern the movements of the celestial bodies, and lastly, from the tribute of our admiration called

forth by those conquests from the dominion of the unknown, which have been achieved by observation and intellectual research. The sense of this regularity and periodicity had impressed itself so early on the minds of men, that we often find it reflected in their forms of speech, indicating a reference to the preordained course of the heavenly bodies. To this it may be added, that among the laws which men have as yet been enabled to recognise in the material universe, those which regulate the movements of bodies in celestial space are perhaps the most admirable by their simplicity; being founded exclusively on the measure and distribution of aggregated ponderable matter, and its powers of attraction. The impression of the sublime arising from the sensibly vast and immeasurable, passes, almost unconsciously to ourselves, by virtue of the mysterious bond which links the sensuous with the supersensuous, into a higher region of ideas. There dwells in the image of the immeasurable, the boundless, the infinite, a power which disposes the mind to a serious and solemn tone, with which, as with the impression of whatever is intellectually great or morally exalted, emotion mingles.

The effect which the occurrence of unwonted celestial phænomena produces so generally and simultaneously on entire masses of population, testifies the influence of this association of feelings. The power exercised on more sensitive minds by the simple aspect of the star-strewn canopy of heaven, is further augmented by augmented knowledge, and by the application of instruments, which, invented by man, extend his visual powers, and with them the horizon of his observation. The impression of the incomprehensible immensity of the universe thus subjected to law and regu-

lated order, calls forth the feeling of tranquillity and repose. This feeling takes from the unsearchable depths of space, as of time, that which to the excited imagination had otherwise attached to them, of shrinking awe. In all regions of the earth, man, in the impulse of his natural sensibility, has praised the "calm repose of a star-light summer night."

If, then, immensity of space and magnitude of mass belong especially to the Sidereal portion of the Physical Description of the Universe, in which the eye is the only organ of contemplation, on the other hand the Telluric portion has the more than countervailing privilege, of offering a greater scientifically-distinguishable variety in the multifarious elementary substances with which it is conversant. We are in contact with terrestrial nature through the medium of all our senses; and as astronomy, or the knowledge of moving luminous heavenly bodies, has given occasion to the admirable augmentation which has taken place in the brilliant domain of the higher analysis and the wide range of optical science; so, on the other hand, it is the terrestrial sphere alone which, by the diversity of substances, and the complicated action of the forces manifested in those substances, has afforded the foundation of chemistry, and of all those physical sciences which treat of phænomena distinguishable from light- and heat-exciting undulations. Each of these great divisions of the study of Nature exercises, in virtue of the character of the problems which it proposes for solution, a special influence on the character of the intellectual labour to which it has given rise, and to the enrichment of human knowledge which is the fruit of that labour

All cosmical bodies, excepting our own planet, and the aerolites which are attracted by it, are, so far as we can

recognise them, simply homogeneous gravitating matter, without specific, or, what is called, elementary diversity of substance. This simplicity, however, is by no means to be regarded as belonging to the actual nature and constitution of those distant orbs themselves; it is founded solely on the simplicity of the conditions of which the assumption suffices for the explanation and prediction of their movements in celestial space, and (as I have already more than once had occasion to remark: Kosmos, Bd. i. S. 56—60, and 141; Bd. iii. S. 4, 18, 21—25, 594, and 626; Engl. Vol. i. p. 50—54 and 126; Vol. iii. p. 4, 18, 21—25, 421, and 448) on the exclusion of all direct and assured perception on our parts of diversities of substance in the heavenly bodies. We thus have presented to us for solution the great problem of a system of celestial mechanics, subjecting all that is variable in the uranological sphere solely to the doctrine of the laws of motion.

Periodical changes in the appearance of the light reflected from the surface of Mars do indeed indicate difference of seasons and meteorological phænomena, *i. e.* precipitations occasioned by the cooling of the atmosphere of the planet at its opposite poles in the opposite portions of its year (Kosmos, Bd. iii. S. 513; Engl. p. 371). Guided by analogy and connection of ideas, we may indeed *infer* from hence the existence of ice or snow (and therefore of oxygen and hydrogen, the constituents of water) in the planet Mars; as we may also infer the existence of different kinds of rock in the erupted masses and flat annular plains of the Moon; but we cannot assure ourselves of the actual state of things by direct observation. Newton only permitted himself to entertain conjectures as to the elementary constitution

of the planets belonging to the same solar system, as we learn from an important conversation held by him with Conduit at Kensington (Kosmos, Bd. i. S. 137 and 407; Engl. p. 122 and 389). The uniform spectacle of apparently homogeneous gravitating matter aggregated in celestial orbs has struck the imagination of man in various ways, the most remarkable instance being, perhaps, the myth which lends to the soundless deserts of space the magic of musical tones (Kosmos, Bd. iii. S. 437—439; Engl. p. 315—317).

In the all but infinite variety of chemically-distinct substances, and the manifestations of force which they exhibit,—in the formative and productive activity of the whole of organic nature, and of many inorganic substances,—and in the changes which produce the never-ending appearance of origination and destruction,—the order-seeking intellect, ranging through the terrestrial domain, looks, often unsatisfied, for simple laws of motion. In the Physics of Aristotle, it is said, "the fundamental principles of all nature are variation and motion; whoso does not recognise these, does not recognise nature" (Phys. Auscult. iii. 1, p. 200, Bekker); and, alluding to "diversity of substance," "difference of essence," he terms motion, in respect to the category of "qualitatives," "transformation," αλλοιωσις; a term very different from simple "mixture," μίξις, and an interpenetration, which does not exclude re-separation (De gener. et corrupt. i. 1, p. 327).

The unequal ascent of fluids in capillary tubes; endosmose, so active in all organic cells, which is probably a consequence of capillarity; the condensation of gases in porous bodies (oxygen gas in platinum under a pressure of above 700 atmospheres, and carbonic acid gas in beech-

wood-charcoal, where more than a third of the quantity of gas is condensed in a liquid form on the walls of the cells); and the chemical action of "contact substances," which by their presence (catalytically) occasion or destroy combinations without taking themselves any part therein,—all these phænomena teach that substances exercise upon each other, at infinitely small distances, an attraction dependent on their specific essences. Such attractions cannot be conceived without motion excited by them, although escaping our visual perception. In what relation this mutual molecular attraction, viewed as a cause of perpetual motion on the surface of the globe, and, it is highly probable, also in its interior, may stand to the attraction of gravitation, by virtue of which the planets, and the central bodies around which they revolve, are in perpetual motion, is wholly unknown to us. Even a *partial* solution of such a purely physical problem would constitute the highest and most glorious prize, which the combination of experiment with intellectual reasoning could attain in such lines of research. In the above allusions to molecular, and what is commonly called Newtonian attraction, I have not been willing to employ the latter term to designate exclusively the attraction which prevails in the regions of space, extending to illimitable distances, and acting inversely as the square of the distance. Such an application of the word Newtonian appears to me almost an injustice to the memory of that great man, who already recognised both the manifestations of force, whilst at the same time, as if anticipating future discoveries, he attempted, in his appendix to his work on Optics, to attribute capillarity, and the little that was then known of chemical affinity, to universal gravitation (Laplace, Expos.

du Syst. du Monde, p. 384; Kosmos, Bd. iii. S. 22, and 32 Anm. 39; Engl. p. 21, and vii., Note 39).

As in the visible world it is especially on the oceanic horizon, that optical illusions often hold out to the expectation of the discoverer the promise of new lands, which for a time remains unrealised, so has it been on the bounds of the ideal horizon, in the remotest regions of the intellectual world, that to the earnest inquirer many promising hopes have arisen and have again faded away. Great discoveries in recent times are indeed suited to heighten expectation on this subject; such are contact-electricity,—rotation-magnetism, which can be excited by substances either in a fluid or a solid state,—the attempt to regard all affinity as a consequence of the electric relations of atoms to a predominating polar force,—the theory of isomorphous substances applied to the formation of crystals,—many phænomena of the electric state of the living muscular fibre,—and the knowledge gained of the influence of the height of the Sun (the temperature-raising solar rays) on the greater or less magnetic susceptibility of a constituent of our atmosphere, oxygen. When we see new light dawning from a previously unknown group of phænomena in the material world, we may the more hopefully think ourselves on the verge of new discoveries, if the relations of the new facts to those with which we were previously acquainted, appear obscure or even contradictory.

I have by preference adduced examples in which *dynamic* actions of *motive* forces of attraction appear to open the path by which we may hope to approach nearer to the solution of the problems of the original, invariable (and therefore termed elementary) heterogeneity of substances (as oxygen,

hydrogen, sulphur, potash, phosphorus, tin, &c.), and the degree of their tendency to combine, or their chemical affinity. Differences of form and composition are, however, I here repeat, the elements of the whole of our knowledge of matter; they are the abstractions under or through which, by means of measurement and analysis, we endeavour to comprehend the whole of the material world. The detonation of fulminates with a slight *mechanical* pressure, and the still more violent explosion, accompanied by fire, of chloride of nitrogen, contrast with the explosive combination of chlorine and hydrogen gas on exposure to the direct incidence of a solar ray, more especially the violet ray. Change of substance, combination and decomposition, mark the perpetual circuit of the elements in inorganic nature, as well as in the animated cells of plants and animals. "The quantity of the existing substances, however, remains the same; the elements only change their relative positions."

Thus the sentence anciently enounced by Anaxagoras, still holds good, that "that which exists in the universe suffers neither augmentation nor decrease;" and that what his contemporaries termed the perishing of things, was a mere dissolution of previous combinations. It is indeed true that the terrestrial sphere, inasmuch as it is the seat of the only organic corporeal world accessible to our observation, appears a continual field of death and of corruption; but it is also true, that the great natural process of slow combustion, which we term corruption, does not bring with it any annihilation. The disengaged substances recombine in other forms, which, by the forces residing in them, become the means of calling forth fresh life from the bosom of the earth.

B.

RESULTS OF OBSERVATION IN THE TELLURIC PORTION OF THE PHYSICAL DESCRIPTION OF THE UNIVERSE.

In endeavouring to bring an immeasurable mass of materials, consisting of the most multifarious objects, into the desired subjection,—*i. e.* to arrange the phænomena in such a connection and sequence as shall facilitate the insight into their causal connection,—it is necessary, in order to make the representation at once clear and comprehensive, not to allow particular details, especially in long-explored and mastered fields of observation, to escape from the higher point of view of cosmical unity. The telluric, as opposed to the uranologic portion of the Physical Description of the Universe, naturally divides itself into two parts :—the Inorganic and the Organic domain. The *first* comprises the magnitude, figure, and density of the terrestrial globe; its internal heat, and electro-magnetic activity; the mineralogical constitution of the earth's crust; the reaction of the interior of the planet on its surface, acting dynamically as in earthquake movements, and chemically as in the processes of the formation and alteration of rocks; the partial covering of the solid surface by the liquid expanse of seas; the outline and configuration of the more elevated portions of the solid surface, forming continents and islands; and the general, outermost, gaseous envelope of the earth, the atmosphere. The *second*, or the

organic domain, will embrace, not the different animated or vegetable forms themselves, as in a description of nature, but rather their places in reference to the solid and liquid parts of the earth's surface, or the geography of plants and animals and the gradations of races and tribes distinguishable in the specific unity of mankind.

This division into two domains also belongs in a certain degree to antiquity. A line of demarcation was drawn between the elementary processes, change of form and transition of substances into each other, on the one hand, and the life of plants and animals on the other. The distinction between plants and animals (in the entire absence of any means of augmenting the visual powers) (1) was made to rest either solely on intuitive apprehension, or on the dogma of self-nourishment (Aristot. de Anima, ii. 1, T. i. p. 412, a 14 Bekker), and internal impulse or volition leading to motion. That kind of intellectual conception which I have called intuitive apprehension, or rather intuition, and still more, the Stagirite's own peculiar acuteness in the fruitful combination of ideas, led him to discern the apparent transition from the inanimate to the animate, from the elementary substance to the plant, and even to the view that, in the progressively higher processes of formation, there might be found intermediate gradations from plants to the lower kinds of animals. (Aristot. de part. Animal. iv. 5, p. 681, a 12; and Hist. Animal. viii. 1, p. 588, a 4 Bekker). The history of organic nature (taking the word history in its primary signification,—therefore in relation to earlier periods of time, to the periods of the ancient Floras and Faunas) is so intimately allied to geology, *i. e.* to the sequence of the successive superimposed strata of the earth's surface,

and to the chronometry of the elevations of lands and mountains, that it has appeared to me preferable, for the sake of the links connecting such great and widely-diffused phænomena, not to make the otherwise very natural separation of organic and inorganic a primary element of classification in a work on the Cosmos. The object in this work is not to treat subjects morphologically, but rather to view Nature, and the active forces of Nature, in their totality.

I.

Magnitude, Figure, and Density of the Earth—Internal Heat of the Earth, and its Distribution—Magnetic Activity, manifesting itself in variations of Inclination, Declination, and Force—Magnetic Storms—Polar Light, or Aurora.

There is contained in all languages, though it may be etymologically represented under different symbolical forms, an expression equivalent to that of "Nature," (and sometimes, as man is inclined to refer always primarily to the seat of his own habitation, "Terrestrial Nature"), designating the result of the harmonious concurrent action of a system of impelling forces, which are themselves only known to us through their effects in the production of motion, combination, and separation, and partially in the formation of organic tissues (living organisms), which reproduce their like. "Naturgefühl," the feeling for, or sentiment of Nature, is, in dispositions accessible to such impressions, the vague, but exciting and elevating impression of this general systematic action. Curiosity is first arrested by the relations in space and magnitude of our planet, a globular mass of almost imperceptible minuteness in the immeasurable universe. A system of concurrent activities uniting, or (by polar action) separating, substances, supposes dependence of each particle on the others, in the elementary processes of inorganic formation, as well as in the elicitation and main-

tenance of organic life. The size and figure of the terrestrial globe—its mass (*i. e.* the quantity of matter of which it consists, and which, compared with its volume, determines its density, and thereby, under certain conditions, its internal constitution, as well as the measure of its attracting force);—are all connected with each other by an interdependence, more distinctly recognisable and more accessible to mathematical treatment than that which we have as yet been able to perceive in the vital processes above alluded to, in thermal currents, or in the telluric conditions of electro-magnetism and chemical changes of substances. Relations which, in complicated phænomena, we are not yet able to measure quantitatively, may yet exist, and may be rendered probable on grounds of induction.

Although we cannot, in the present state of our knowledge, reduce to the same law the two kinds of attraction—viz. that which acts at sensible distances (as the mutual gravitation of the heavenly bodies), and that which acts at distances immeasurably small (molecular or contact-attraction),—yet it is not on that account the less credible, that capillary attraction, and the action of endosmose, so important in the ascent of sap and other juices and for the whole of vegetable and animal physiology, may be affected by the amount and relations of gravity, as may also electro-magnetic processes and chemical action. We may assume, to take extreme circumstances, that if our planet had only the mass of the Moon, so that the force of gravity at its surface should have only about one-sixth of its present intensity, the meteorological processes of our climates, the hypsometrical relations of our mountain-chains, and the physiognomy (facies) of our vegetation, would all be very

different from what they are. The *absolute* size of our globe, with which we are about to occupy ourselves, becomes important in the general economy of nature, on account of the proportion subsisting between it and the mass and velocity of rotation; for, speaking generally throughout the universe, if the dimensions of planets, the quantity of substance, or mass, of each, and their respective velocities and distances, were all to be increased or decreased in one and the same proportion, then in this ideal Macro- or Micro-cosmos, all phænomena dependent on relations of gravitation would remain unchanged. (2)

α. *Magnitude, Figure (Ellipticity), and Density of the Earth.*

(Extension of the "Picture of Nature" in Kosmos, Bd. i. S. 171—178 and 420—425. In the English, Vol. i. p. 154—161 and 400—405.)

The Earth has been measured and weighed to obtain its exact form, density, and mass. The precision which has been constantly aimed at in these terrestrial determinations has at the same time benefitted astronomy by the improvements in measuring instruments and in methods of analysis which the pursuit has called forth, no less than by the solution of the problem itself. Indeed, a considerable part of the operation of the measurement of degrees is itself astronomical; altitudes of stars determine the curvature of the arc of which the length is found by geodesical operations. Methods have been discovered, in the higher branches of mathematics, for obtaining from given numerical elements the solution of the difficult problems of the form of the Earth,—the figure of equilibrium of a fluid homogeneous

mass, or that of a solid shell-like non-homogeneous mass, rotating round a fixed axis. From Newton and Huygens, the most celebrated geometricians of the eighteenth century were occupied with this solution. Here, as always, it is well to remember, that whatever is achieved by intellectual effort and mathematical research, derives its value, not alone from that which is actually discovered and added to the domain of human knowledge; but also, and more especially, from the higher perfection and power to which the analytical instrument has been wrought in the course of the investigation.

"The geometrical, as distinguished from the actual physical, figure of the Earth,(3) is determined by what would be the surface of water in a network of canals everywhere covering the earth in connection with the ocean. This ideal geometric surface (the extension and completion of the oceanic surface) is everywhere perpendicular to the direction of the forces compounded of all the attractions proceeding from the several particles of which the earth is composed, combined with the centrifugal force corresponding to its velocity of rotation.(4) This figure can only be regarded as approximating, on the whole, very nearly to that of an elliptic spheroid of revolution; for irregularities in the distribution of the mass in the *interior* of the earth produce, not only local variations of density, but also irregularity in the *geometric* surface, which is the product of the concurrent action of unequally distributed elements. The *physical* surface of the earth is that of the actually existing land and water." Geological reasons render it not improbable that accidental alterations which may take place in the molten materials in the interior of the earth, easily

mobile notwithstanding the great pressure to which they are subject, may cause internal displacements of mass, which may modify, after very long intervals of time, the geometric surface itself in the curvature of the meridians and parallels within small distances; while the physical surface is exposed, in its oceanic portion, to a constantly recurring periodical displacement of mass by the ebb and flow of the tides. The smallness of the effect on gravitation of the first-named supposed class of phænomena, may cause a very slow and gradual change taking place in continental regions to escape discovery by actual observation: according to Bessel's calculation, in order to increase the height of the pole at any particular place only 1″, there must be supposed to be displaced in the interior of the earth a mass of such weight as that, its density being taken as equal to the mean density of the earth, its bulk shall be equal to 114 cubic geographical (German) miles. (German geographical miles are 15 to a degree). (5) Large as this volume may appear for the supposed displaced mass when we compare it with the volume of Mont Blanc, of Chimborazo, of Kinchinjunga, it will seem less so when we recollect that the terrestrial spheroid contains above 2650 millions of such cubic miles.

The problem of the figure of the Earth—the connection of which with the geological question respecting an earlier fluid state of the rotating planetary body had already been recognised at the great epoch (6) of Newton, Huygens, and Hooke,—has been attempted to be solved, with unequal success, in three different ways: by astro-geodesical measurement of degrees, by pendulum experiments, and by the inequalities of the Moon in latitude and longitude. The first method

divides itself in its application into two: viz. the measurement of degrees of latitude on an arc of the meridian, and the measurement of degrees of longitude on different parallels. Although seven years have now elapsed since I included in my "General Representation of Nature" the results of Bessel's important memoir on the dimensions of the Earth, yet his investigation cannot even now be replaced by a more comprehensive one, based on later measurements of degrees. There are, indeed, to be soon expected, one important addition, and one more perfect revision,—the publication of the nearly completed Russian Arc, extending almost from the North Cape to the Black Sea; and the careful comparison of the standard employed in the Indian Arc, whereby the results of the latter will be more assured. By the determinations published by Bessel in 1841, the mean dimensions of our planet, according to the most exact investigation (7) of ten measured arcs, are as follows: the semi-major axis of the spheroid of rotation, which approximates most nearly to the irregular figure of the Earth, is 3272077,14 toises; the semi-minor axis, $3261139^t,33$; the length of a quadrant of the Earth, $5131179^t,81$; the length of a mean degree of latitude, $57013^t,109$; the length of a degree of longitude, on the equator, $57108^t,520$, and in latitude 45°, $40449^t,371$; the ellipticity, or flattening at the poles, $\frac{1}{299 \cdot 152}$; and the length of a German geographical mile of 15 to an equatorial degree, $3807^t,23$. The following Table shows the increase of the length of a degree of the meridian from the equator to the poles, as found by observation,—modified, therefore, by local disturbances of attraction:—

Countries.	Geographical latitude of the middle of the measured arc.			Length of the measured arc.			Length of a degree of the meridian in the latitude of the middle of the arc, expressed in Toises.	Observer.
	°	′	″	°	′	″		
Sweden	66	20	10	1	37	19·6	57195·8	Svanberg.
	66	19	37	0	57	30·4	57201·8	Maupertius.
Russia	56	3	55·5	8	02	28·9	57137·0	Struve, Tenner.
Prussia	54	58	26	1	30	29	57145·2	Bessel, Baeyer.
Denmark	58	8	13·7	1	31	53·3	57093·1	Schumacher.
Hanover	52	32	16·6	2	0	57	57126·4	Gauss.
England	52	35	45	3	57	13·1	57075·0	Roy, Mudge, Kater.
	52	2	19·4	2	50	23 5	57071·8	
France	44	51	2·5	12	22	12·7	57012·5	Delambre, Méchain, Biot, Arago.
North America	39	12	0	1	28	45	56889·6	Mason, Dixon.
India	16	8	21·5	15	57	40·7	56773·6	Lambton, Everest,
	12	32	20·8	1	34	56·4	56759·0	Lambton.
Quito (S. lat.)	1	31	0·4	3	7	3·5	56864·6	La Condamine, Bouguer.
Cape of Good Hope (S. lat.)	33	18	30	1	13	17·5	57035·6	Lacaille,
	35	43	20	3	34	34·7	56932·5	Maclear.

The determination of the figure of the Earth by the measurement of degrees of longitude in different parallels of

latitude, requires great exactness in the observed differences of longitude. Cassini de Thury and Lacaille, as early as 1740, availed themselves of powder signals in the measurement of an arc perpendicular to the meridian in the parallel of Paris. At a more modern period, the length of parallel arcs, and the differences of longitude, were measured with far better instrumental means, and with greater certainty, in the course of the great Trigonometrical Survey of England; the determinations were between Beechy Head and Dunnose, and between Dover and Falmouth,(8) the differences of longitude being indeed only 1° 26′ and 6° 22′ respectively. The most brilliant operation of this kind was undoubtedly the measurement of the arc between the meridians of Marennes on the west coast of France, and Fiume. It crosses the most western chain of the Alps, and the Lombard plains of Milan and Padua: the measurement was executed by Brousseaud and Largeteau, Plana and Carlini, and extends over a direct distance of 15° 32′ 27″, almost entirely under the middle parallel of 45°. The many pendulum experiments which were made in the neighbourhood of the mountains confirmed in a remarkable manner the previously recognised influence of local attraction, shown by the comparison of the astronomical latitudes with the results of the geodesical measurements.(9)

Next to these two classes of direct measurements of degrees, (*a*) of meridianal, and (*b*) of parallel arcs, mention should be made of a purely astronomical mode of determining the Earth's figure. It is founded on the influence exercised by the Earth on the motion of the Moon (*i. e.* on the inequalities in her latitude and longitude). Laplace, who first recognised the cause of these inequalities, also indicated

the mode of applying them to this question, and sagaciously remarked, that this method has a great advantage which detached measurements of degrees and pendulum experiments cannot have, in giving in a single result the *mean* figure of the Earth (or the form belonging to the *entire* planet). I recall with pleasure the happy expressions by which this method was characterised by its inventor, (10) "that an astronomer, without quitting his observatory, might learn from the motions of a single heavenly body the precise form of the Earth which he inhabits." According to a final revision of the inequalities in latitude and longitude of our satellite, and the employment of several thousand observations by Burg, Bouvard, and Burckhardt, (11) Laplace found for the figure of the Earth an ellipticity of $\frac{1}{306}$th, which approximates very nearly to that given by the measurements of degrees, viz. $\frac{1}{299}$.

The oscillations of a pendulum offer a third method of determining the figure of the Earth (*i. e.* the ratio of the major to the minor axis, under the assumption of the form being that of an elliptic spheroid), by finding the law according to which the force of gravity increases in proceeding from the equator to the poles. The oscillations of a pendulum had been first applied to the determination of time by the Arabian astronomers, and in particular by Ebn-Junis, at the end of the tenth century, in the brilliant period of the Abasside Caliphs; (12) and after being neglected for six centuries, were again employed by Galileo and by Riccioli at Bologna. (13) By combination with wheel-work for regulating the march of time-pieces (employed first in the imperfect attempts of Sanctorius at Padua in 1612, and subsequently in the finished work of Huygens in 1656), the

pendulum became, in Richer's comparison of the march of the same astronomical clock at Paris and at Cayenne (in 1672), the first experimental proof of the variation in the force of gravity in different latitudes. Picard had, indeed, been occupied in the preparations for this important expedition, but he does not on that account attribute to himself the merit of the first proposition. Richer left Paris in October 1671, and Picard, in the description of his measurement of a degree, published in the same year (1671), remarked simply (14), that "at a meeting of the Academy, one of the members expressed an opinion, that, on account of the Earth's rotation, weights might be found to be less heavy, or have less gravity, at the equator than at the pole." He adds doubtingly, "that, indeed, according to some observations made in London, Lyons, and Bologna, it would seem as it the seconds pendulum required to be *shortened* in approaching the equator: but that, on the other hand, he is not sufficiently convinced of the accuracy of those measurements, because, at the Hague, the length of the seconds pendulum was found to be quite the same as at Paris, notwithstanding the difference of latitude." We unfortunately cannot learn when Newton first obtained the knowledge, which was to him so important, of Richer's pendulum results, obtained in 1672 but first published in a printed form in 1679; or of Cassini's discovery, in 1666, of the ellipticity of Jupiter; or, at least, we cannot learn it with the same exactness and certainty which we possess in regard to his very late knowledge of Picard's arc. At a period when, with so happy an emulation, theoretical views stimulated to the undertaking of observations, and the results of observation reacted in their turn on theory, the

exact knowledge of particular dates has a great interest in the history of the establishment of physical astronomy on mathematical foundations.

If the direct measurements of arcs of meridians and parallels (particularly the French arc ([15]) of the meridian between lat. 44° 42′ and 47° 30′, and the parallel arc between points situated east and west of the Graian, Cottian, and Maritime Alps), ([16]) show great *deviations* from the mean ellipsoidal figure of the Earth,—the irregularities in the measure of the ellipticity given by pendulum stations differently distributed or grouped as respects geographical relations, are much more striking. The determination of the figure of the Earth by the increase or decrease of gravity (intensity of attraction at the respective places) supposes that the intensity of the force at the surface of the terrestrial rotating spheroid has remained the same as at the period of solidification from a fluid state, and that no subsequent changes of density have taken place in it.([17]) Notwithstanding the great improvement of instruments and methods by Borda, Kater, and Bessel, there are at present in both hemispheres, from South Shetland to Spitzbergen—therefore from 62° 56′ S. to 79° 50′ N. latitude—only between 65 and 70 points very irregularly distributed over the earth's surface, ([18]) at which the length of the simple pendulum has been determined with the same exactness as the position of the place in latitude, longitude, and height above the sea.

The pendulum experiments made on the part of an arc of the meridian measured by the French astronomers, as well as the observations made by Captain Kater in connection with the Trigonometrical Survey of Great Britain, showed that the

results could by no means be represented in every case by a variation in the force of gravity in the ratio of the square of the sine of the latitude. The English government decided, therefore (at the recommendation of the Vice-President of the Royal Society, Davies Gilbert), on sending out a scientific expedition for the extension of the inquiry at stations far more widely removed from each other, which was entrusted to my friend Edward Sabine, who had previously accompanied Captain Parry, on his first Arctic expedition of discovery, as astronomer. He visited in the years 1822 and 1823, for the purpose of pendulum experiments, the West Coast of Africa from Sierra Leone to the Island of St. Thomas near the equator, Ascension, the coast of South America from Bahia to the mouth of the Orinoco, the West Indies, and New York, and subsequently the high Arctic north as far as Spitzbergen, and a previously unvisited part of East Greenland, concealed behind formidable icy barriers, in lat. 74° 32′. This brilliant and successfully executed undertaking had the advantage of being directed to a single subject of research as its principal object, and of comprehending points extending over 93 degrees of latitude.

The field of observation along the French arc was indeed less near to the equinoctial and Arctic regions, but it had the great advantage of a linear distribution of the places of observation and of direct comparison with the curvature found by the geodesical and astronomical operations. Biot, in 1824, continued the series of pendulum experiments from Formentera in 38° 39′ 56″ lat., where he had previously observed with Arago and Chaix, to Unst, the northernmost of the Shetland Islands, in 60° 45′ 25″; and in conjunction with

Mathieu made similar determinations on the parallel of Bourdeaux, Figeac, and Padua, to Fiume.[19] These pendulum results, taken together with those of Sabine, give for the whole northern quadrant the ellipticity of $\frac{1}{290}$; but if divided into two parts, the results are far less accordant,[20] *i. e.* from the equator to lat. 45° $\frac{1}{278}$, and from lat. 45° to the pole $\frac{1}{306}$. The influence of the presence of the denser kinds of rock, such as basalt, greenstone, diorite, and melaphyre, as compared with the specifically lighter sedimentary and tertiary formations, as well as the effect of volcanic islands,[21] in increasing the intensity of gravity, has been recognised in most cases in both hemispheres; but there still remain anomalies which are not wholly explained by the geological character of the rocks accessible to our observation.

For the southern hemisphere we possess a small series of excellent observations, thinly scattered, however, over a wide extent, by Freycinet, Duperrey, Fallows, Lütke, Brisbane and Rumker, [and Foster]. They confirm what had already appeared so strikingly from the observations in the northern hemisphere, that the intensity of gravitation is not the same at all places having the same latitude; so much so, that the increase of gravity from the equator to the poles would appear to be subjected to unequal laws under different meridians. Lacaille's pendulum experiments at the Cape of Good Hope, and those made in the Spanish voyage of circumnavigation of Malaspina, might have caused it to be believed that the southern hemisphere was in general considerably more flattened than the northern one; but, as I have already stated,[22] more exact results at the Falkland

Islands, and in New Holland, compared with New York, Dunkirk, and Barcelona, have proved the contrary.

From what has been said, it appears to follow, that the pendulum,—(no unimportant instrument of geological investigation, being a kind of sounding-line by which the deep unseen terrestrial strata may be reached),—affords us less well-*assured* knowledge respecting the figure of our planet than that which may be gained from measurements of degrees and the lunar movements. Strata concentric, elliptic, each taken separately homogeneous, but increasing in density according to certain functions of the distance in proceeding from the surface towards the centre of the earth (which are the supposed theoretical conditions), may, by their actual diversity of constitution, position, and order of density in different parts of the earth, occasion at the surface local deviations in the force of gravity. If the circumstances which produce these deviations are much more recent than the hardening of the outer terrestrial crust, we may conceive the figure of the earth's surface as not having been locally modified by the internal movement of the molten masses. At all events, the diversities of the results of measurements by means of the pendulum are far too great to be now ascribed to errors of observation. When pendulum stations are grouped or combined in various ways, so as to give accordance or systematic regularity in the general results derivable from such combinations, they are still always found to give a greater amount of ellipticity than measurements of degrees have hitherto done.

If we take the result of these latter as now most generally received, according to Bessel's last determination, viz.:

$\frac{1}{299 \cdot 152}$; the increase of the radius of the earth at the equator, (23) in comparison with that at the poles, is the difference between 3272077 and 3261139 toises; being 10938 toises, or 65628 Paris, or 69943 English, feet, or not quite $11\frac{1}{2}$ geographical miles. As it has been customary to compare this equatorial convexity of the earth's surface with well-measured mountain-elevations, I select as objects of comparison the highest known summit of the Himalaya, Kinchinjunga, 4406 toises, 26436 Paris or 28178 English feet, as measured by Colonel Waugh, and that part of the Plateau of Thibet which is nearest to the Sacred Lakes, Rakas-Tal and Manassarovar, and which, according to Lieut. Henry Strachey, attains the mean elevation of 2400 toises, or about 15347 English feet. It would follow from hence that the enlargement of our planet in its equatorial zone is not three times as great as the elevation of the summit of the highest terrestrial mountain above the level of the sea, nor five times as great as the general elevation of the Eastern Plateau of Thibet.

This is the proper place for remarking that differences between the results obtained for the amount of the earth's ellipticity by measurements of degrees taken alone, and by the combination of measurements of degrees and pendulum experiments, are actually far smaller than we might be inclined to suppose at the first sight of the fractions in which those results are expressed. (24) The difference between $\frac{1}{310}$ and $\frac{1}{280}$ as the extreme results for the inequality of the equatorial and polar axes, is little more than 6600 Paris (7034 English) feet: not twice the height of such small mountains as Vesuvius and the Brocken.

As soon as the measurements of degrees in very different latitudes had manifested that the interior of the earth cannot be assumed to be of uniform density, since their results showed an ellipticity much inferior to that assumed by Newton ($\frac{1}{230}$), and greatly exceeding $\frac{1}{578}$, the amount corresponding to the hypothesis of Huygens of the whole attraction being concentrated at the centre of the earth,—the connection of the amount of ellipticity with the "law of density" in the interior of the terrestrial spheroid could not but become an important subject for analytical investigation. Theoretical speculations on gravity led early to the consideration of the attraction which might be exercised by mountain masses rising like banks from the dry bottom of the atmospheric ocean. Newton had already examined, in his "Treatise of the System of the World in a popular way, 1728," how much a mountain 2500 Paris feet high, and having a diameter of 5000 such feet, would deflect the plumb line from its vertical direction. It was probably this examination which gave occasion to the not very satisfactory experiments of Bouguer at Chimborazo,([25]) and of Maskelyne and Hutton at Schehallien in Perthshire, near Blair Athol; to the comparison of the lengths of the seconds pendulum on the sea-shore and at 6000 French feet above the sea (at the Hospice on Mount Cenis by Carlini, and near Bourdeaux by Biot and Mathieu); and lastly, to the delicate and alone decisive experiments of Reich and Baily, made with the ingeniously-devised "Torsion Balance," invented by John Mitchell, ([26]) and transmitted through Wollaston to Cavendish.

These three different modes of determining the density of

our planet have already been so far treated of in detail, (Kosmos, Bd. i: S. 176—178 and 424, Anm. 6; Engl. p. 159 —160 and 404), that it will be sufficient to subjoin here the result of the fresh experiments by Reich in 1847 and 1850, published in a later memoir by that indefatigable investigator.(27) According to the present state of our knowledge, the results of the three methods are the following; the density of water being taken as unity.

The Schehallien experiments; mean of Playfair's maximum 4·867, and his minimum 4·559	4·713
Pendulum observations at Mont Cenis, by Carlini, with Giulio's correction	4·950
Torsion Balance; Cavendish, according to Baily's calculation..	5·448
Reich, 1838	5·440
Baily, 1842	5·660
Reich, 1847—1850	5·577

The mean of the two last results gives the density of the earth 5·62; much exceeding, therefore, that of the densest and finest-grained basalts (according to Leonhard's numerous experiments, from 2·95 to 3·67); exceeding that of magnetic iron ore (4·9—5·2); and but little inferior to the native arsenic of Marienberg or Joachimsthal. I have already remarked (Kosmos, Bd. i. S. 177; English edition, p. 160), that, viewing the great proportion of the visible strata of our continents which are secondary, tertiary, or alluvial, (the collective extent of volcanic or basaltic islands is exceedingly small,) the average density of

the superficies of that part of the outer crust of the globe which is not covered by water, probably scarcely amounts to between 2·4 and 2·6. If, with Rigaud, we take the ratio of the dry land to the water-covered surface as 10 : 27, and remember that ocean soundings have given a depth or stratum of water of more than 27000 English feet, it will follow that the mean density of the external portion of our planet, consisting partly of land and partly and more extensively of water, scarcely attains the density of 1·5. It is certainly in correct, as a celebrated geometrician, Plana, has remarked, that the author of the "Mécanique céleste" should have ascribed to the exterior terrestrial crust the density of granite, which density has itself been rated rather highly by Laplace at =3·0, ([28]) whence he obtained the density of the centre of the earth=10·047. The latter is, according to Plana, 16·27 if we take the upper strata at=1·83 (which differs little from 1·5 or 1·6 as the density of the *total* crust). The horizontal pendulum (the torsion balance) may, indeed, have been called, as well as the vertical pendulum, a geognostical instrument; but the geology of the inaccessible internal parts of the earth is, like the astrognosy of "dark heavenly bodies," only to be treated with great caution. In the volcanic section of this work, I shall have to touch on questions which have been propounded by others, respecting currents in the generally fluid interior of the earth, the probability or improbability of a movement of periodical ebb and flood in detached basins not entirely filled, and on the existence of spaces of less density beneath upheaved mountain-chains. ([29]) We ought not to omit in the "Cosmos" any consideration to which actual observations, or not remote analogies, appear to lead.

β. *Internal Heat of the Earth, and its Distribution.*

(Enlargement of the Representation of Nature in Kosmos, Bd. i. S. 179—184, 425—427, Anm. 7—10; Engl. Vol. i. p. 161—167 and p. 405—407; Notes 137—140).

Considerations respecting the internal heat of the earth, the importance of which has been so much enhanced by their now so generally acknowledged connection with volcanic action and phænomena of elevation, are based partly on direct, and therefore incontestable observation of temperatures in springs, borings, and mines; and partly on analytical combinations respecting the gradual cooling down of our planet, and the influence which the diminution of temperature may have exercised on its velocity of rotation,(30) and on the direction of internal thermal currents in primeval time. The form of the flattened terrestrial spheroid is itself again dependent on the law of increasing density in concentric superimposed non-homogeneous shells. The first-mentioned, which is the experimental, and therefore more assured portion of the investigation to which we here confine ourselves, can, however, only shed light on the earth's crust of inconsiderable thickness; while the second, which is the mathematical part of the inquiry, is, from the nature of its applications, suited to afford negative rather than positive results. Offering the charm which is afforded by sagacious combinations of thought,(31) it leads to problems which, together with conjectures respecting the origin of volcanic forces, and the reaction of the molten interior against the solid outer shell, or crust, cannot remain altogether unnoticed. Plato's geognostic myth of the Pyriphlegethon,(32) as the origin or fount of all hot springs and volcanic

fiery currents, had its source in the early and generally felt desire of discovering a common cause for a great and complicated series of phænomena.

Viewing the variety of conditions which the surface of the earth presents in respect to the reception and absorption of the solar rays, and to the facility with which heat radiates from the earth into space, as well as the great diversity in the conduction of heat by reason of the various composition and density of different rocks, it is not a little wonderful that where observations have been made with care and under favourable circumstances, such (generally speaking) accordant results for the increase of temperature with increasing depth should have been obtained in such different localities. Borings, especially where they are filled with water rendered rather thick and muddy by the presence of clay, and thus less favourable to the generation of internal currents, and supposing there to be few lateral openings from whence affluents from cross-fissures at different heights could be received, present the greatest certainty; and on this account, as well as on account of their great absolute depth, we will begin with the two most remarkable Artesian Wells,—that of Grenelle at Paris, and of Neu-Salzwerk in the Oeynhausen Soolbade, near Minden. I subjoin the most accurate determinations at both.

According to the measurements of Walferdin,(33) to whose ingenuity we are indebted for a variety of delicate apparatus for determining temperatures at depths either of the sea or of wells, the floor of the Abattoir du Puits de Grenelle is $36^{m},24$ above the sea. The highest level to which the water of the spring ascends is $33^{m},33$ higher. This total height to which the water rises above the level of the sea

($69^m,57$) is in absolute elevation about 60 metres lower than the out-cropping of the green-sand stratum in the hills near Lusigny, south-east of Paris, to the infiltrations of which the ascent of the water in the Artesian Well of Grenelle is ascribed. The water was reached by the boring at a depth of 547^m (1683 Paris, or 1794 English, feet) below the floor of the Abattoir, or 1675 English feet below the level of the sea: the whole ascent of the water, therefore, is 1903 English feet. The temperature of the spring is 27°·75 Cent. (81·95 Fahr.) The increase of temperature is in this case 1° of the Centigrade thermometer for every 99½ Paris feet, or 1° of Fahr. for 58·9 English feet.

The height at which the boring commenced at Neu-Salzwerk, near Rehme, is 218 Paris feet above the level of the sea (*i. e.* above the Pegel at Amsterdam), and it reached an absolute depth of 2144 Paris feet below the point at which the work began. The Sool-spring, therefore, which comes out impregnated with much carbonic acid, is 1926 French, or 2053 English, feet below the level of the sea; a relative depth the greatest perhaps which has ever been reached by man. Its temperature is 32°·8 Cent., or 91°·04 Fahr.; and as the mean annual temperature of the air at Neu-Salzwerk is about 9°·6 Cent., or 49°·28 Fahr., we may infer an increase of temperature of 1° Cent. for 92·4 Paris, or 98·5 English, feet, or of 1° Fahr. for 54·72 English feet.

The boring of the well of Neu-Salzwerk,(34) compared with that of Grenelle, has a greater absolute depth of 461 French feet; a greater relative depth below the level of the sea of 354 French, or 377 English, feet; and the temperature of its water is 5°·1 Cent., or 9°·18 Fahr., higher. The increase of temperature is therefore nearly $\frac{1}{17}$

less rapid at Paris, or at the rate of about 7·1 French feet more for each centesimal degree. I have already noticed(35) that a very similar result was obtained by Auguste de la Rive and Marcet in a boring examined by them at Bregny, near Geneva, having a depth of only 680 French, or 724·7 English feet, although situated at more than 1600 English feet above the Mediterranean.

If to the three wells which have been mentioned, which attain depths of from 680 to 2144 Paris, or 725 to 2285 English, feet, we add that of Wearmouth, near Newcastle (being the pit waters of the coal-mine in which, according to Phillips, men work at a depth of 1404 French, or 1496 English, feet below the level of the sea), we find the remarkable result, that at four places so distant from each other, the increase of temperature only varies between 91 and 99 Paris feet for 1° Centigrade.(36) Such an accordance cannot, however, from the nature of the means employed, be everywhere looked for in inquiries into the internal heat of the earth at given depths. Admitting that the meteoric water falling on heights, and penetrating by infiltration, produces by hydrostatic pressure, as in connected tubes, the ascent of springs at lower points; and that the subterranean waters assume the temperature of the strata with which they come into contact; they may nevertheless, in certain cases, have channels of communication with still deeper clefts, from whence they may receive accessions of still warmer water from unknown depths. Such an influence, which is to be altogether distinguished from different degrees of conducting power in the surrounding rocks, may take place at points very distant from the shaft or boring of the well. It is probable that the subterranean waters exist sometimes in

confined spaces, as in river-like fissures (and hence it often happens that, of several borings in near proximity to each other, only some are successful), while sometimes they may form basins of wide extent in a horizontal direction,—a distribution very favourable for yielding supplies of water, and which only in very rare cases betrays an open communication with the surface of the earth by the presence of eels, shells, and vegetable remains. If from such causes as have been mentioned, ascending springs are sometimes warmer than might be anticipated from the small depth of the boring through which they rise, on the other hand an opposite effect is produced by colder waters flowing in laterally through openings from cross-fissures.

It has been remarked already that the maxima and minima of the variations of atmospheric temperature, occasioned by the height of the sun at the different hours of the day and seasons of the year, reach points situated in the same vertical line, at small depths below the surface, at very different times. According to the always very exact observations of Quételet,([37]) the diurnal variations cease to be sensible at Brussels at the small depth of 3·8 French feet; and in respect to annual variations, a thermometer placed 24 French, or 25·6 English, feet below the surface at Brussels, did not show the maximum of temperature during the year until the 10th of December, and the minimum until the 15th of June. Also, in the fine series of experiments made by Forbes in the vicinity of Edinburgh, on the conducting power of different kinds of rock, the maximum temperature in the basaltic trap of Calton Hill was observed to take place on the 8th of January, at a depth of 23 feet.([38]) According to Arago's series of many years' observations in the garden of the

Observatory at Paris, only very slight differences of temperature are discernible at 28 Paris, or 30 English, feet below the surface. Bravais still found a difference of 1° Cent. (1°·8 Fahr.) at a depth of 26½ French feet in the high North, at Bossekop in Finmarken, lat. 69° 58′. The difference between the maximum and minimum temperatures of the year becomes rapidly less as we descend; diminishing, according to Fourier, in geometrical, as the depth increases in arithmetical, progression.

In reality, however, the depth of the "invariable stratum" below the surface, or the depth at which no sensible change of temperature takes place, is not everywhere the same. It depends on the latitude of the place, on the heat-conducting power of the rock, and on the amount of difference between the temperatures of the hottest and coldest seasons. In the latitude of Paris (48° 50′), the observations in the "Caves de l'Observatoire" give 86 Paris feet, or 92 English feet as the depth, and 11°·834 Cent., or 53°·3 Fahr., as the temperature of the "invariable stratum." Since Cassini and Legentil in 1783 fixed a very exact mercurial thermometer in those subterranean spaces which are parts of ancient stone-quarries, the mercury has risen 0°·22 (Cent.) in the tube.(39) It is still doubtful whether this rise is caused by an accidental alteration in the thermometer scale, (which, however, was very carefully verified by Arago in 1817), or whether it is to be ascribed to a real increase of temperature. The mean temperature of the air at Paris is 10°·822 Cent., or 51°·48 Fahr. Bravais believes the thermometer in the Caves de l'Observatoire to be *below* the invariable stratum; although Cassini considered he had found a difference of two-hundredths of a centesimal degree

between the winter and summer temperatures,(40) the winter temperature being the higher. If we take the mean of many observations of temperature at and below the surface of the ground between the parallels of Zurich (lat. 47° 22′) and Upsala (lat. 59° 51′), we find a mean increase of 1° Cent. for the depth of 67½ French, or 72 English, feet. The differences due to latitude are not more than from about 13 to 16 English feet, and do not show any regular systematic variation from south to north; probably because the undoubtedly existing effect of latitude is at present inextricably blended with the influence of the varying heat-conducting powers of the different rocks, and with errors of observation.

As, according to the theory of the distribution of heat, the underground stratum in which we begin to find no difference of temperature in the course of the annual cycle, is so much the less deep beneath the surface as the maxima and minima of temperature in the year are less distant from each other, my friend Boussingault was led by this consideration to the ingenious and convenient method of determining the mean temperature of places within the tropics (more particularly within 10° on either side of the equator) by observing a thermometer buried about a foot deep within a *well-covered space.* At the most different hours, and even in different months, (as is shown by the experiments of Colonel Hall near the sea-shore of Choco, in Tumaco; those of Salaza at Quito; and those of Boussingault in the Vega de Zupia, at Marmato, and Anserma Nuevo in the Cauca Valley), the temperature did not vary two-tenths of a centesimal degree (0°·36 Fahr.), and was identical within almost the same limits with the mean atmospheric temperature at places where the latter had been derived from hourly observations.

It is well deserving of notice that this agreement remained the same whether the "thermometric soundings" of only one foot were made on the hot shores of the Pacific at Guayaquil and Payta, or at an Indian village on the side of the Volcano of Purace, the height of which above the level of the sea I found by barometric measurements to be 1356 toises (or 8671 English feet). The mean temperatures differed at these different elevations fully 14° Cent. (25°·2 Fahr.) (41)

Two observations made by myself in the mountains of Peru and Mexico, are, I think, deserving of particular attention, because made in mines situated at elevations higher than the summit of the Peak of Teneriffe; and higher, I believe, than any mines into which a thermometer has yet been taken. Thirteen thousand feet above the level of the sea, I found the subterranean air 14° Cent. warmer than the external air. The little town of Micuipampa,(42) in Peru, is situated, according to my determinations of its geographical position and elevation, in 6° 43′ S. latitude, and at a height of 1857 toises (11875 English feet) above the sea, at the foot of the Cerro de Gualgayoc, celebrated for its mineral (silver) wealth. The summit of this almost isolated, castle-like, and picturesque mountain is 240 toises above the pavement of the street of Micuipampa. The temperature of the external air at a proper distance from the entrance of the Mina del Purgatorio was 5°·7 Cent. (42°·26 Fahr.); but everywhere in the interior (at a height of about 2057 toises, or 13153 English feet above the sea) I saw the thermometer show 19°·8, being a difference of 14°·1 Cent., or 25°·4 Fahr. The limestone rock was perfectly dry, and there were very few miners at work. In

the Mina de Guadalupe, which is at the same elevation, I found the internal temperature 14°·4 Cent. (57°·9 Fahr.), the difference from the external air being therefore 8°·7, or 15°·8 Fahr. The waters which were streaming down in this very wet mine showed 11°·3 Cent. (52°·3 Fahr.) The mean annual temperature of the air at Micuipampa is probably not above 7½° Cent., or 45½° Fahr. In Mexico, in the rich silver mines of Guanaxuato, I found at the Mina de Valenciana[43] the temperature of the external air near Tiro Nuevo (7122 Paris, or 7590 English, feet above the sea) 21°·2 Cent., or 70°·16 Fahr.; and the air in the deepest part of the mine, in the Planes de San Bernardo (1630 English feet below the opening of the shaft of Tiro Nuevo), fully 27° Cent., or 80°·5 Fahr., which is about the mean temperature of the shore of the Gulf of Mexico. In a part of the mine situated 147 feet higher than the floor of the Planes de San Bernardo, there bursts out from the rock a spring of water of the temperature of 29°·3 Cent., or 84°·74 Fahr. The mountain town of Guanaxuato, situated, according to my determination, in 21° N. lat., has a mean temperature falling, approximately, somewhere between 15°·8 and 16°·2 Cent., (60°·44 and 61°·16 Fahr.) It would be unsuitable to enter here into conjectures, difficult to establish on any very certain grounds, as to the causes, possibly of very local influence, which thus raise the temperature of subterranean spaces, in ranges of mountains from six to thirteen thousand feet high.

A remarkable contrast to the above is presented by the circumstances of the ground-ice in the steppes of Northern Asia. Even the existence of this phænomenon was formerly doubted, notwithstanding the testimony early

given by Gmelin and Pallas concerning it. It is only very recently, that, through the excellent investigations of Erman, Baer, and Middendorff, correct views have been gained respecting the extent and thickness of this stratum of subterranean ice. From the descriptions of Greenland by Crantz, of Spitzbergen by Martens and Phipps, and of the shores of the Sea of Kara by Sujeff, an incautious generalisation had represented the whole northern part of Siberia as destitute of vegetation, and with a constantly frozen and snow-covered surface, even in the plains. The extreme limit of the growth of high forest-trees in Northern Asia is not the parallel of 67° latitude, as was long assumed, and as is actually the case near Obdorsk, owing to the influence of sea-winds and the vicinity of the Gulf of Obi. The valley of the great river Lena has lofty trees up to the latitude of 71°. In the desert islands of New Siberia large herds of reindeer and countless lemmings still find sufficient vegetable sustenance([44]). The two Siberian journeys of Middendorff, a traveller eminent for the spirit of observation as well as for boldness of enterprise and perseverance in laborious research, were made from 1843 to 1846, and were directed northwards, into the Taymir country, to nearly 76° N. lat.; and to the south-east as far as the upper Amour and the Sea of Ochozk. The first of these adventurous journeys led the learned traveller into a previously wholly unvisited region, the more important and interesting because situated at an equal distance from the east and west coasts of the old continent. The instructions of the Petersburg Academy of Sciences, commended to him as a leading object of his expedition (in conjunction with the limits of the various forms of organic life towards the high north, depending

principally on climatic relations), the accurate determination of the temperature of the soil, and the thickness of the subterranean or ground-ice. He accordingly examined the latter questions by means of borings and excavations from 21 to 61 feet deep, at more than twelve points (at Turuchansk, on the Ienisei, and on the Lena), at distances of from 1600 to 2000 geographical miles apart.

The most important point, however, for geothermic observations, was the Schergin Shaft(45) at Iakutzk (lat. 62° 2′), where the subterranean icy stratum has been pierced for a thickness of more than 382 English feet. Thermometers have been inserted in the side walls of the shaft, at eleven points situated vertically in respect to each other, between the surface of the earth and the deepest part of the shaft reached in 1837. The observer, in descending, had to read the thermometer scales standing in a bucket, and holding by one hand to the rope. The series of observations, of which the mean error is estimated at only 0°·25 Cent., or 0°·45 Fahr., extended over the interval from April 1844 to June 1846. The decrease of cold was not indeed always in proportion to the depth at each of the separate points, but on the average the increase of temperature with increasing depth was found as follows:—

Engl. Feet.	Réaumur. °	Fahrenheit. °
50	−6·61	17·13
100	−5·22	20·25
150	−4·64	21·56
200	−3·88	23·27
250	−3·34	24·49
382	−2·40	26·60

By a thorough discussion of all the observations, Middendorff obtained, as the general rate of increase of temperature,(46) 1° of Réaumur for between 100 and 117 English feet, or 1° Fahr. for from 44·4 to 52·1 English feet. This is a more rapid rate of increase than is given by several very accordant results from different excavations in Middle Europe (see above, p. 37). The mean annual temperature of Iakutzk is considered to be −8°·13 Réaum., or 13°·71 Fahr. Neveroff's observations, continued during fifteen years (1829—1844), give the variation of temperature between winter and summer so great, that sometimes the temperature of the air, for 14 successive days in July and August, is from 20° to 23°·4 Réaum., or from 77° to 84°·6 Fahr.; while for 120 successive days in winter (November to February) the cold fluctuates between −33° and −44°·8 Réaum., or −42°·25 and −68°·8 Fahr. The depth beneath the surface of the earth at which the lower limit of the frozen ground, or the temperature of 0° Réaum. and Cent., or 32° Fahr., would be met with, is calculated approximately from the increase of temperature found in piercing the icy stratum so far as has yet been done. Middendorff's estimate, from his observations in the Schergin Shaft, in accordance with the much earlier one of Erman, assigns from 612 to 642 French, or 652 to 684 English, feet. On the other hand, the increase of temperature in the excavations of Mangan, Schiloff, and Davydoff (scarcely four miles from Iakutzk, in the chain of hills on the left bank of the Lena), which, however, are not quite sixty feet deep, would place the temperature of 0° (or 32° Fahr.), at a depth of little more than 300 feet.(47) Is this great

difference in the two situations more than accidental? A numerical determination depending on such inconsiderable depths must be regarded as exceedingly uncertain, and the increase of temperature may not always follow a uniform law. Ought we to infer that if a gallery were to be driven horizontally for many hundred fathoms from the lowest depth of the Schergin Shaft, it would encounter everywhere, and in every direction, frozen earth, and that with a temperature of $-2°{\cdot}5$ Cent. below 32°?

Schrenk has examined the ground-ice in $67\frac{1}{2}°$ lat. in the Samoied country, at Pustoienskoy Gorodok. In this case the sinking of the well was aided by the application of fire. In the middle of summer the frozen stratum was encountered at a depth of little more than 5 feet; it was followed through a thickness of 67 feet, when the work was suddenly stopped. The neighbouring lake of Ustie continued to be frozen over and passable by sledges throughout the summer of 1813.(48) On my Siberian expedition with Ehrenberg and Gustav Rose, we had a hole dug in the boggy or turfy soil near Bogoslowzk (lat. 59° 44′) on the road to the Turjin Mine(49) in the Oural Mountains. At a depth of about $5\frac{1}{2}$ feet, we came upon pieces of ice forming a kind of breccia with frozen earth; then solid ice, which continued to the depth of 10 or 11 feet further, at which we left off.

The geographical extent of the ground- or subterranean-ice,—*i. e.* the position and course of the southern limit, in the old continent from Scandinavia to the eastern coast of Asia, at which we begin to find in August, and throughout the year, ice or frozen earth at a certain depth, is, according to Middendorff's sagacious generalisations from observation, like all other geothermic relations, often more depen-

dent on local circumstances than on the temperature of the atmosphere. No doubt the latter has on the whole the most determining influence; but yet, as Kupffer has already remarked, the isogeothermal lines are not parallel in their concave and convex inflections to the climatic isothermals which are given by the mean atmospheric temperature. The amount of rain, and the depth to which it penetrates, the ascent of warm springs from depths, and the very various conducting power of the soil,(50) all appear to be particularly influential. "At the northernmost point of Europe, in Finmarken, in 70° and 71° lat., there is no connected 'ground-ice.' Proceeding eastward to the valley of the Obi, we find the ground-ice at Obdorsk and Beresow 5° more southerly than the North Cape. The cold of the ground continues to increase as we advance eastward, with the exception of Tobolsk on the Irtish, where the temperature of the ground is lower than at Witimsk in the valley of the Lena, which is 1° more to the north. At Turuchansk (65° 54′ lat.) the ground is still not frozen, but the limit at which the ground-ice begins is very near. At Amginsk, south-east of Iakutzk, the ground is as cold as at Obdorsk, 5° further to the north; so also at Oleminsk on the Ienisei. From the Obi to the Ienisei, the curve which bounds the ground-ice appears to rise 2° of latitude more towards the north; and then to re-descend, to cross the valley of the Lena, almost 8° south of the parallel in which it crosses the Ienisei. Further to the east the line re-ascends towards the north."(51) Kupffer, who has visited the mines of Nertschinsk, has pointed out, that apart from the great connected region of the ground-ice, the same phænomenon occurs more to the south in detached patches, or, as it were,

in an insular manner. It is quite independent, generally speaking, of the limits of vegetation and of the presence of high trees.

The gradual acquirement of a true general or cosmical view of the thermal relations of the crust of the earth in the northern parts of the old continent, is an important step in the progress of knowledge, as is the recognition that the limit of the ground-ice, as well as the limits of particular mean annual temperatures, and of the growth of trees, are found in very different latitudes in different meridians,—a fact which must occasion the production of perpetual thermal currents in the interior of the earth. In the north-west of America, Franklin found the ground frozen in the middle of August, at a depth of 17 inches. At a more easterly part of the coast, in 71° 12′ latitude, Richardson saw in July the ice-stratum thawed as far down as three feet below the herb-covered surface. It is to be desired that scientific travellers may soon obtain for us a more general knowledge of the geothermic relations subsisting in this part of the world and in the southern hemisphere. Research into the connection of phænomena leads us most surely to the recognition of the causes of apparently complex or anomalous facts, or of what is sometimes too hastily called irregularity.

γ. Magnetic Activity of the Earth in its three manifestations of Force, Inclination, and Declination—Points (termed Magnetic Poles) at which the Inclination is 90°*—Line on which no Inclination is observed (Magnetic Equator)—Four Points of greatest, but unequal, Intensity of the Magnetic Force—Curve or Line of the weakest Magnetic Force—Extraordinary Disturbances of the Declination (Magnetic Storms)—Polar Light.*

(Extension of the Representation of Nature, in Kosmos, Bd. i. S. 184—208, and 427—442, Anm. 11—49; Bd. ii. S. 372—376, and 515, Anm. 69—74; Bd. iii. S. 399—401, and 419, Anm. 30: Engl. Vol. i. p. 167—189, and 407—424, Notes 141—179; Vol. ii. p. 331—335, and cxix., Notes 509—514, bis; Vol. iii. p. 289—290, and civ., Note 489.)

The magnetic constitution of our planet can only be inferred from those manifestations of its magnetic force which present measurable relations in reference either to place or time. These manifestations are characterised by *perpetual variability* in the phænomena which they present, and this in a far higher degree than such other variable phænomena as the temperature, aqueous vapour, and electric tension of the lower strata of the atmosphere. The continual changes which take place in the kindred magnetic and electric conditions of matter, form an essential distinction between the phænomena of electro-magnetism, and those which depend on that primary, fundamental force of molecular and mass-attraction of all matter, which, at unchanged distances,

remains ever the same. The investigation of the dominion of law amidst variability, is itself the proximate object, or the goal immediately aimed at, in every investigation into a force in nature. While the labours of Coulomb and Arago have demonstrated that the electro-magnetic process can be elicited in the most various substances, Faraday's brilliant discovery of diamagnetism, on the other hand, shows us here also, in the distinction of north and south axiality in one class of substances, and east and west axiality in others, that influence of the diversity or heterogeneity of substances of which molecular or mass-attraction is wholly independent. Oxygen gas, enclosed in a thin glass tube, when placed under the action of a magnet in its vicinity, assumes "paramagnetically" a north and south direction, like iron; nitrogen, hydrogen, and carbonic acid gas, remain unaffected; while phosphorus, leather, and wood, under the same circumstances, range themselves "diamagnetically," *i. e.* in an equatorial or east and west direction.

The facts known in Greek and Roman antiquity were: the adhesion of iron to the loadstone; magnetic attraction and repulsion; the propagation of the attracting influence through iron vessels, and also through rings([52]) forming links in a chain (one ring being in contact with the loadstone); and the non-attraction of wood, or of other metals than iron. Of the polar directive force which magnetism could impart to a body susceptible of its influence, the early western nations (Phœnicians, Etruscans, Greeks and Romans) knew nothing. It is not until the 11th and 12th centuries of our era that we find among the European nations any knowledge existing of this "directive force,"

which has exerted so powerful an influence on the improvement and extension of navigation, and, in consequence of the practical and material services which it has thus rendered, has given so persistent an impulse to the study of an all-pervading, yet formerly little regarded, natural force. In the history of the principal epochs in the Physical Contemplation of the Universe,(53) the subject of the earth's magnetism, which we now bring under one general view, assigning the several sources or authorities from whence the information is derived, fell under several different chronological heads, and was there divided among different sections.

It is among the Chinese that we find the first application of the magnetic directive force to practical purposes by the employment of magnetised needles floating on water, which goes back to an epoch anterior perhaps to that of the Doric migration and the return of the Heraclides to the Peloponnesus. It is remarkable that in this part of Asia the use of needles, the south end of which was the one distinguished, as with us the north, commenced in land journeys before their employment in sea navigation. Instead of a ship's compass they used a magnetic car, on the front part of which a floating needle carried a little figure, whose outstretched arm and hand pointed to the south. Such an apparatus, Fse-nan (indicator of the south), was presented, under the dynasty of the Tscheu, 1100 years before our era, to the ambassadors from Tunkin and Cochin-china, to guide them across the great plains on their return from China to their own country. The magnetic car continued to be used as late as the 15th century.(54) Many such instruments were kept in the Emperor's palace, and it

was also customary to use them in determining the direction of the walls when building Budhistic convents. Their frequent employment led some of the more acute thinkers to form physical speculations respecting the nature of the magnetic phænomena. The Chinese panegyrist of the magnetic needle, Kuopho, a contemporary of Constantine the Great, compared the attractive force of the magnet to that of rubbed amber. "It is," he says, "as if a mysterious breath passed through both, communicating itself with the swiftness of an arrow." The symbolical expression of "a breath" reminds us of the equally symbolical expressions used in Grecian antiquity by the founder of the Ionic school, Thales, in reference both to the magnetic stone and to amber, which were said to be "animated," or imbued with a "soul" or "spirit," meaning evidently an indwelling principle of motive activity.(55)

As the too great mobility of these Chinese floating needles was found inconvenient, they were replaced in the beginning of the 12th century by a different construction, in which the needle was suspended freely in the air by a cotton or silken thread, quite in the manner of the "Coulomb" suspension, which was first employed in Europe by Gilbert. With this improved apparatus,(56) the Chinese even determined early in the 12th century the amount of the west declination, which appears to undergo only very slow and minute changes in that part of Asia. At length the compass came to be employed at sea as well as on land. Under the dynasty of Tsin, in the 4th century, Chinese ships guided by compasses visited the ports of India and the eastern coast of Africa.

Two centuries earlier, in the reign of Marcus Aurelius Antoninus (called An-tun by the Chinese writers of the dynasty of Han), Roman legates had come by water by Tunkin to China; but it was not through so transitory a communication that the use of the compass reached Europe; where it was not introduced until the 12th century, after its use had become general throughout the Indian seas and the coasts of Persia and Arabia. The introduction was effected either directly by the influence of the Arabians, or through the medium of the Crusaders, who since 1096 had been in contact with Egypt and the Levant. In historical inquiries of this class, the only epoch which can be assigned with certainty is that which must be regarded as the latest or limiting date. In a political satirical poem of Guyot of Provins, in 1199, the mariner's compass is spoken of as an instrument long known among the nations of Christendom; and this is also the case in a description of Palestine which we owe to Jaques de Vitry, Bishop of Ptolemais, and which was finished between 1204 and 1215. Guided by the compass, the Catalans sailed to the northern isles of Scotland, and to the west coast of tropical Africa; the Basques to the whale fishery; and the Normans to the Azores (the Bracix Islands of Picigano). In the first half of the 13th century, the Spanish "Leyes de las Partidas," the work "del sabio Rey Don Alonso el Nono," extols the compass-needle as the faithful mediatrix (medianera) between the "magnetic stone"—"la piedra"—and the "north star." Gilbert, in his celebrated work "de Magnete Physiologia nova," speaks of the compass as a Chinese invention, but adds, which is clearly incorrect, that it was first brought to Italy by Marco Polo, "qui apud Chinas artem pyxidis didicit." As

Marco Polo began his travels in 1271, and returned in 1295, the evidence of Guyot de Provins and Jaques de Vitry shows that the compass was used in European navigation at least sixty or seventy years before the commencement of his travels. The names of Aphron and Zohron, given to the north and south poles of the needle by Vicentius of Beauvais in his "Mirror of Nature" (1254), indicate that Arab pilots were the channel through which the nations of Europe received the Chinese compass, being obviously derived from that learned, ingenious, and active race, traces of whose language are so frequent in our star-maps, though appearing there too often in a mutilated form.

From all these circumstances, there can be no doubt that the general employment of the magnetic needle in ocean navigation by the Europeans from the 12th century, (and in a limited degree probably still earlier), proceeded from the Mediterranean and its shores, and took place chiefly through the agency of Moors, Genoese, Venetians, Majorcans, and Catalans. Catalan sailors, under the conduct of the celebrated navigator, Don Jaime Ferrer, advanced in 1346 to the mouth of the Rio de Ouro, 23° 40′ N. latitude, on the west coast of Africa; and from the evidence of Raymund Lully (in his nautical work, Fenix de las Maravillas del Orbe, 1286), it appears that long before Jaime Ferrer, the Barcelonese used sea-charts, astrolabes, and sea-compasses.

The knowledge of the existence of a greater or less amount of magnetic declination (its early name was simply "variation," without any adjunct) had naturally been also diffused over the Mediterranean, by report from China, through the medium of Indian, Malay, and Arab mariners.

This element, so indispensable for the correction of ships' reckonings, was, at that early period, determined less often by sunrise and sunset than by the pole-star, and in either case with much uncertainty; it was, however, entered on nautical charts,—for example, on the rare chart of Andrea Bianco, sketched in 1436. Columbus, who was certainly not the first who recognised the fact of magnetic declination,—any more than Sebastian Cabot, of whom it has sometimes been stated,—has the praise of having been the first who determined the position of a line of no declination, which he did astronomically, in $2\frac{1}{2}$ degrees east of the Island of Corvo (one of the Azores), on the 13th of September, 1492. In traversing the western part of the Atlantic Ocean, he was the first who observed the "variation" change gradually from north-east to north-west. He was led thereby to conceive the idea, which has so often engaged the attention of navigators in later centuries, of making use of the declination lines,—which he imagined to be parallel to the meridians,—for finding the longitude. We learn from his journals, that, on his second voyage (1496), when uncertain of his position, he sought it by means of *declination observations*. A view of the possibility of such a method was also, without doubt, that infallible secret of the longitude at sea, which, on his death-bed, Sebastian Cabot boasted of possessing through special divine revelation.

In the excitable imagination of Columbus, there were connected with the Atlantic line of no declination other and rather fanciful ideas of supposed change of climate, anomalous figure of the terrestrial spheroid, and extraordinary views respecting the movements of the heavenly bodies, in all of which he found reasons for proposing the

conversion of a physical line into a political line of demarcation. The "raya," on which the "agujas de marear" point direct to the pole-star, became the boundary line between the crowns of Castile and Portugal by virtue of a Papal decree, whose arrogance proved of great and lasting, though undesigned and unforeseen, benefit to the enlargement of nautical astronomy and the improvement of magnetic instruments, in consequence of the importance which naturally attached to determining, with astronomical accuracy, the geographical longitude of such a boundary on both sides of the equator. (Humboldt, Examen critique de la Géogr. T. iii. p. 54.) Felipe Guillen, of Seville (1525), and, at a still earlier period, probably the cosmographer Alonso de Santa Cruz, teacher of mathematics to the young Emperor Charles V., constructed new "variation compasses," with which solar altitudes could be taken. In 1530—a century and a half, therefore, before Halley—the same Alonso de Santa Cruz drew the first general "variation map," founded, it must be admitted, on very imperfect materials. The voyage of Juan Jayme, who sailed from the Philippines to Acapulco with Francisco Gali in 1585, solely for the purpose of trying, during the long passage across the Pacific, a new declination instrument which he had invented, shows how animated an impulse had been given in the 16th century, and after the death of Columbus, to the study of terrestrial magnetism, by the controversy respecting the Papal "line of demarcation."

This disposition to pursue observation could not but be accompanied by its unfailing attendant,—if not, as is still oftener the case, its precursor,—a fondness for theoretical speculations. Many of the old sea-stories of the Indians,

as well as of the Arabs, speak of rocky islands which cause disasters to mariners, either by drawing out, by virtue of their natural magnetic power, all the iron which held the wooden framework of the ship together, or by attracting and immovably enchaining it. Under the influence of such imaginations, the idea of the polar conjunction of all the lines of declination had associated with it, in early times, the more material image of a high *magnetic mountain*, in near proximity to one of the poles of the earth. In the remarkable map of the new continent, appended to the Roman edition of 1508 of Ptolemy's Geography, we find to the north of Greenland (Gruentlant), which is represented as belonging to the eastern part of Asia, the north magnetic pole figured as a mountainous island rising out of the sea. Its position was gradually removed farther to the south in the "Breve Compendio de la Sphera" of Martin Cortez, in 1545, as well as in Livio Sanuto's "Geographia de Tolomeo," in 1588. Great expectations were attached to reaching this point, which was termed "el calamitico;" and from some notion, which was very late in disappearing, it was supposed that whoever should reach the magnetic pole would find "alcun miraculoso stupendo effetto."

Until near the end of the 16th century, the magnetic declination, which is the element exercising the most direct influence on the requirements of navigation, was the only one which received attention. Instead of the one "line of no variation," found by Columbus in 1492, the learned Jesuit Acosta, in 1589, thought, from the information which he had gathered from Portuguese seamen, that he could state, in his excellent work, "Historia natural de las Indias," the

existence of *four* such lines. As a ship's reckoning requires an exact knowledge of the distance passed over, as well as of the exact direction of the course (given by the angle measured by the corrected compass), the introduction of the use of the "log," imperfect as this kind of measurement is even at the present day, was yet an important epoch in the history of navigation. I think I have proved, contrary to the prevailing opinion hitherto, that the first certain evidence[57] of the employment of the log (la cadena de la popa, la corredera) is to be found in Antonio Pigafetta's ship's journal in Magellan's voyage, in an entry appertaining to the month of January, 1521. Columbus, Juan de la Cosa, Sebastian Cabot, and Vasco de Gama, were all unacquainted with the log and its applications. They estimated the ship's rate of movement by the eye alone, and judged of the distance passed over by "hour glasses," *i. e.* by the running-out of sand in the "ampolletas." At length, in 1576, in addition to the horizontal declination from the geographical north, which had been so long exclusively regarded, the second element, the inclination, or dip of the needle below the horizontal line, came also to be measured. Robert Norman, the first who determined it, did so in London with an instrument of his own invention, and with no inconsiderable degree of accuracy. Fully two centuries more elapsed before any attempt was made to measure the third element, viz. the intensity of the earth's magnetic force.

A man whom Galileo admired, although Bacon altogether overlooked his merits, William Gilbert, brought forward, at the end of the 16th century, the first enlarged and comprehensive view[58] of the earth's magnetism. He first

distinguished clearly between magnetism and electricity in respect to their effects, while he yet regarded both as emanations of a single fundamental force inherent in all matter. As is the privilege of genius, from feeble analogies he successfully divined much. From the clear conceptions which he formed of terrestrial magnetism (de magno magnete tellure), he even at that time correctly ascribed the origin of magnetic poles in the upright iron bars of crosses on old church-towers, to impartation from the magnetism of the earth. He was the first in Europe who showed how to render iron magnetic by rubbing it with the loadstone, which indeed the Chinese had known and practised almost 500 years before.([59]) Gilbert also already gave steel the preference over soft iron, because capable of appropriating to itself and retaining more permanently the magnetic force imparted to it.

In the course of the 17th century, the navigation of the Dutch, English, Spaniards, and French (which had so greatly increased in extent through the improvement in the means of determining the direction of a ship's course, and the length or amount of distance traversed by her), augmented the knowledge already possessed of different isogonic lines, and more particularly of the lines of no declination, which, as already mentioned, Acosta had attempted to form into a system.([60]) In 1616, Cornelius Schouten pointed out in the middle of the Pacific Ocean, near the Marquesas, places where the needle had no variation. We still find in this region a singular "closed" system of isogonic lines, within which the declination changes in amount in successive concentric curves.([61]) The eagerness to discover new methods of determining the longitude, for which it was thought not

only that the declination, but also that the inclination, of the magnetic needle might be made available,—(such a use of the inclination, with a clouded starless sky, "per aëre caliginoso," Wright called "worth much gold,") (62)—led to the construction of many and various magnetic instruments, and stimulated the activity of observers. The Jesuit Cabeus of Ferrara, Ridley, Lieutaud in 1668, and Henry Bond in 1676, distinguished themselves in this way. The controversy between Bond and Beckborrow, together with Acosta's view of the existence of four lines of no declination dividing the entire surface of the globe into four parts, may, perhaps, have had some influence on Halley's theory of "four magnetic poles, or points of convergence," projected as early as 1683.

Halley's name constitutes an important epoch in the history of terrestrial magnetism. He assumed the existence in each hemisphere (northern and southern) of two magnetic poles, a stronger and a weaker pole; and we now find an analogous distribution of the magnetic force in four points of maximum force, two in each hemisphere, one stronger than the other, as shown by the rapidity of the vibrations performed by a needle oscillating in the direction of the magnetic meridian. The strongest of Halley's four poles was placed in 70° S. lat. and 120° E. long. from Greenwich, or almost in the meridian of King George's Sound, in New Holland.(63) Halley's three voyages in 1698, 1699, and 1702, followed the first sketch of his theory, which was founded only on the observations obtained on his voyage to St. Helena seven years before, and on the imperfect variation (declination) observations of Baffin, Hudson, and Cornelius von Schouten. Halley's expeditions

were the first undertaken by a government for a great scientific object, viz. for the investigation of an element of the earth's force, on which the safety of navigation especially depends. He advanced as far as 52° S. lat., and was thus enabled to construct the first extensive variation- or declination-chart, which chart now supplies to the theoretical investigators of the 19th century a point of comparison, although not indeed a very remote one, for the representation of the progressive change of position of the declination lines.

It was a happy undertaking of Halley's to connect graphically by lines or curves all the points on the map where the magnetic declination was the same.(64) Clearness of representation, and the advantage of gaining a general view of the connection of detached results, were thus first introduced. My isothermal lines, *i. e.* lines of equal temperature (mean annual, summer, or winter temperature), which have been favourably received by physicists, were formed in strict analogy with Halley's isogonic curves. The object of the isothermal lines, especially since their great extension and improvement by Dove, has been to throw light on the distribution of temperature over the earth's surface, and on the dependence of that distribution in a great degree on the configuration, extent, and relative position of the portions of the surface occupied by land and water. Halley's purely scientific expeditions stand out as the more remarkable, because they were not designed, like so many subsequent expeditions undertaken at the public expense, as voyages for *geographical discovery*, but were strictly for *scientific research*. Halley's stay at St. Helena in 1677 and 1678 had for its fruit, in addition to the data furnished to the

knowledge of terrestrial magnetism, an important catalogue of southern stars, which it may be remarked, in passing, was the first star-catalogue undertaken since the combination of telescopes with measuring apparatus introduced by Morin and Gascoigne.(65)

As the close of the 17th century had been marked by progress towards a better knowledge of the position of the declination lines, and by the first theoretical attempt to determine their points of convergence as magnetic poles, so the first half of the 18th century produced the discovery of the horary periodic variation of the declination. Graham, in London, in 1722, has the uncontested merit of being the first to observe these variations with accuracy and perseverance. Celsius and Hiorter, at Upsala, who were in epistolary communication with Graham,(66) further enlarged the knowledge of the phænomena in question. It was not until the latter part of the century, in 1784—1788, that Brugmanns and Coulomb, the latter gifted with a more mathematical mind, penetrated more deeply into the essence of terrestrial magnetism. Their acutely devised physical experiments embraced the magnetic attraction of all matter, the distribution of the force in a bar-magnet of a given form, and the law of magnetic action at a distance. In the methods adopted by them for obtaining exact results, they sometimes employed the vibrations of a horizontal needle suspended by a thread, and sometimes deflections measured by a torsion balance.

Science is indebted for the first knowledge of the variation in the intensity of the earth's magnetic force at different points of its surface, obtained by the vibration of a needle suspended vertically and placed in the magnetic meridian, solely to the

sagacity of the Chevalier Borda, not by successful experiments made by himself personally, but by those suggested by his sagacious anticipations, and carried into execution in consequence of the influence which he perseveringly exercised on travellers and voyagers preparing for distant expeditions. His long-cherished conjectures were first confirmed by Lamanon, the companion of La Pérouse, in the years 1785—1787. These observations, although their results had been made known so early as the summer of the last-named year to the Secretary of the Académie des Sciences, Condorcet, remained unnoticed and unpublished. The credit of the first, although on this account incomplete, recognition of the important law of the variation of the magnetic force with the magnetic latitude, belongs without dispute to the ill-fated expedition of La Pérouse,(67) the preparations for which were of the highest scientific merit; but the law itself, I venture to believe, first became a living fact in science by the publication of my observations made from 1798 to 1804 in the south of France, in Spain, the Canaries, and the interior of tropical America north and south of the equator, and in the Atlantic and Pacific Oceans. The scientific voyages of Le Gentil, Feuillée, and Lacaille,—the first attempt to construct an inclination map, by Wilke in 1768,—and the memorable voyages of circumnavigation of Bougainville, Cook, and Vancouver,—all deserve honorable mention for the data they afforded in respect to the previously much neglected element of the inclination, so important for the establishment of the theory of terrestrial magnetism. The instruments employed were, indeed, of very unequal merit, and the determinations (which, although widely distributed over the earth's surface, were generally

limited to the sea and to its immediate vicinity) were far from being contemporaneous. Towards the end of the 18th century, the observations of the declination made with better instruments, at fixed stations, by Cassini, Gilpin, and Beaufoy (1781 to 1790), showed more decidedly a periodical influence of hours and seasons, and gave a more animated and general impulse to magnetic research.

In the 19th century, of which little more than the half has now elapsed, this branch of scientific inquiry has assumed a peculiar character distinguishing it from all others. This character consists in an almost simultaneous advance of all parts of the study of terrestrial magnetism, in which physical discoveries relating to the elicitation and distribution of magnetism, and the first and brilliant projection of a theory of terrestrial magnetism based on strict mathematical reasoning, by Friedrich Gauss, have accompanied the unprecedented extension of numerical determinations of all the magnetic elements, —the declination, inclination, and intensity of the force.

The means which have led to this result have been :— the improvement of instruments and methods of observation; scientific naval expeditions, on a scale and in number such as no previous century had witnessed, carefully equipped at the costs of the governments which sent them forth, and favoured by a happy choice of commanders and observers; land journeys, penetrating far into the interior of continents; and lastly, the establishment of a considerable number of fixed observatories, extending partially over both hemispheres, in corresponding north and south latitudes, and in almost antipodal longitudes.

These magnetical and, at the same time, meteorological observatories form a kind of net-work over the earth's

surface, and by the judicious combination of the observations made at them, important and unexpected results have been arrived at. The subjection of the manifestations of the magnetic force, as displayed on the earth's surface, to determinate laws,—which subjection, in relation to all forces, is the proximate, but not the ultimate object of all scientific inquiry,—has been already satisfactorily established and investigated in several particular phases of the phænomena. In the path of physical experimentation, on the other hand, the discoveries which have been made of the relations of terrestrial magnetism to electricity in motion, to radiant heat, and to light; the recent generalisation of the phænomena of diamagnetism, and the discovery of the specific property of the oxygen of the atmosphere to acquire polarity,—all open to us the cheering prospect of a nearer approach to the nature of the magnetic force itself.

In order to justify the praise which I have ventured to bestow on the magnetic labours, taken generally, of the first half of the present century, I append a brief notice of the more prominent among them, arranging them sometimes singly in chronological order, and sometimes, where they appear to have called each other forth, in groups.(68)

1803—1806. Krusenstern's Voyage of Circumnavigation, 1812. The magnetical and astronomical portion of the work is by Horner. (Bd. iii. S. 317.)

1804. Examination of the law of increase of the intensity of the earth's magnetic force north and south of the magnetic equator, founded on observations made from 1799 to 1804. (Humboldt, Voyage aux Régions équinoxiales du Nouveau Continent, T. iii. p. 615—623; Lametherie,

Journal de Physique, T. lxix. 1804, p. 433, with the first sketch of a map of the intensity; Kosmos, Bd. i. S. 432, Anm. 29; Engl. ed. p. 416, Note 159). Subsequent observations have shown that the minimum of intensity is not situated on the magnetic equator; and that the increase of force in either hemisphere does not extend to the magnetic pole.

1805—1806. Gay-Lussac and Humboldt's observations on the magnetic force in the South of France, Italy, Switzerland, and Germany (Mémoires de la Société d'Arcueil, T. i. p. 1—22.) Compare therewith the observations of Quételet, 1830 and 1839, published in the Mém. de l'Académie de Bruxelles, T. xiv., with a map of the horizontal magnetic force between Paris and Naples; Forbes's observations in Germany, Flanders, and Italy, in 1832 and 1837 (Transactions of the Royal Society of Edinburgh, Vol. xv. p. 27); the very exact observations of Rudberg in France, Germany, and Sweden, 1832; and the observations of Bache (Director of the Coast-Survey of the United States), of inclination and force, at 21 stations in 1837 and 1840.

1806—1807. A long series of observations at Berlin on the horary variations of the declination, and on the recurrence of "magnetic storms," (perturbations or disturbances), by Humboldt and Oltmanns, made chiefly at the solstices and equinoxes for five or six, or sometimes even nine, successive days and nights, with a Prony's magnetic telescope reading to 7 or 8 seconds of arc.

1812. Statement by Morichini at Rome that unmagnetised steel needles became magnetic by contact with light (with the violet ray). On the long controversy occasioned by this

statement, and by Mary Somerville's ingenious experiments, down to the wholly negative results of Riess and Moser, see Sir David Brewster's Treatise on Magnetism, 1837, p. 48.

1815—1818, and 1823—1826. The two voyages of circumnavigation of Otho von Kotzebue; the first in the 'Rurik,' the second in the 'Predprijatie,' five years later.

1817—1848. The series of great scientific naval expeditions sent by the French government, and which have been so fruitful in results contributing to the knowledge of terrestrial magnetism; beginning with Freycinet, in the 'Uranie,' 1819—1820; followed by Duperrey, in the 'Coquille,' 1822—1825; Bougainville, in the 'Thetis,' 1824—1826; Dumont d'Urville, in the 'Astrolabe,' 1826—1829, and in the Antarctic Regions in the 'Zélée,' 1837—1840; Jules de Blosseville in India, 1828 (Herbert, Asiatic Researches, Vol. xviii. p. 4; Humboldt, Asie centrale, T. iii. p. 468), and in Iceland, 1833 (Lottin, Voyage de la Recherche, 1836, p. 376—409); du Petit Thouars (with Tessau), in the 'Vénus,' 1837—1839; Le Vaillant, in the 'Bonite,' 1836—1837; the expedition of the Commission Scientifique du Nord (Lottin, Bravais, Martins, and Siljeström) to Scandinavia, Lapland, the Feroe Islands, and Spitzbergen, in the corvette 'Recherche,' 1835—1840; Bérard, to the Gulf of Mexico and North America, 1838, and to the Cape of Good Hope and St. Helena in 1842 and 1846, (Sabine, in the Phil. Trans. for 1849, Pt. ii. p. 173); and Francis de Castelnau, Voyage dans les parties centrales de l'Amérique du Sud, 1847—1850.

1818—1853. The long series of important expeditions sent to the Arctic Seas by the British Government, to which

the first impulse was given by the praiseworthy zeal of John Barrow: Edward Sabine's magnetical and astronomical observations in John Ross's Voyage to Davis Straits, Baffin's Bay, and Lancaster Sound, 1818; and in Parry's Voyage (in the 'Hecla' and 'Griper') through Barrow's Straits to Melville Island, 1819—1820; Franklin, Richardson, and Back, 1819—1822; the same, 1825—1827; and Back alone, 1833—1835. (In the first of these last-named expeditions, almost the only food for several weeks was a lichen, *Gyrophora pustulata*, Tripe de Roche of the Canadian hunters, chemically examined by John Stenhouse in the Phil. Trans. for 1849, Pt. ii. p. 393); Parry's second expedition with Lyon, in the 'Fury' and 'Hecla,' 1821—1823; and third voyage with James Clark Ross, in 1824—1825; Parry's fourth voyage (an attempt to reach the North Pole over the ice to the north of Spitzbergen) with the same, and Lieutenants Foster and Crozier, 1827, when they reached lat. 82° 45′: John Ross, with his distinguished nephew James Clark Ross (the expenses of this voyage, which proved so perilous from its long duration, 1829—1833, were defrayed by a private individual, Felix Booth); Dease and Simpson (of the Hudson's Bay Company) 1838—1839; and recently, in the search for Sir John Franklin, the voyages of Austin, Ommaney, and Penny, 1850—1851. Of these, Penny advanced farthest to the north,—to lat. 77° 6′ in Victoria or Queen's Channel, which opens from Wellington Strait.

1819—1821. Bellinghausen's voyage in the Antarctic Seas.

1819. The publication of the great work of Hansteen, Magnetismus der Erde, which had, however, been finished as early as 1813. This excellent work has exercised

an unmistakable influence in the animation and better direction of researches in terrestrial magnetism. It was followed by Hansteen's general maps of lines of equal inclination and equal force for a considerable portion of the earth's surface.

1819. Observations of Admiral Roussin and Givry on the coast of Brazil, between the mouths of the Amazon and the River Plate.

1819—1820. Oersted's great discovery of the fact that a conductor traversed by an electric current, forming a complete and continuous circuit, exercises, so long as the current continues, a definite influence on the direction of the magnetic needle dependent on their relative position. The earliest extension of this discovery, as well as of those of the separation of the metals from the alkalies, and of double polarisation, the most brilliant of the discoveries of the age,(69) was Arago's observation that a connecting wire through which an electric current flows, though made of copper or platinum, attracts and retains iron filings like a magnet; and also, that needles placed inside a galvanic coil receive opposite poles according as the turns of the coil are given an opposite direction (Annales de Chimie et de Physique, T. xv. p. 93). The discovery of these phænomena, which were traced under a variety of circumstances, was followed by Ampère's ingenious theoretical combinations on the reciprocal electro-magnetic actions of the molecules of ponderable bodies. These combinations were supported by much new and ingeniously-devised apparatus, and led to a recognition of laws in many phænomena of magnetism which had previously appeared contradictory.

1820—1824. Wrangel and Anjou's journeys to the North

Coast of Siberia and on the Icy Sea. (Important phænomena of the Aurora Borealis: Th. ii. S. 259.)

1820. Scoresby, Account of the Arctic Regions: (experiments on the magnetic force: Vol. ii. p. 537—554.)

1821. Seebeck's discovery of thermo-magnetism and thermo-electricity. The contact of two metals (first tried with bismuth and copper), or differences of temperature at the two points of contact of a metallic ring, are recognised as sources of excitement of magneto-electric currents.

1821—1823. Weddell's voyage in the Southern Polar Sea, to latitude 74° 15′ S.

1822—1823. Sabine's two important expeditions for the exact determination of the magnetic inclination and variations of the magnetic force, and of the length of the pendulum in different latitudes (west coast of Africa to the Equator, Brazil, Havanna, Greenland to latitude 74° 23′, Norway and Spitzbergen to latitude 79° 50′). This comprehensive work was published in 1824: (Account of Experiments to determine the Figure of the Earth, p. 460—509.)

1824. Erikson's magnetic observations on the shores of the Baltic.

1825. Arago discovered rotation-magnetism. This unexpected discovery was a consequence of his noticing, when at Greenwich, that the time required by a dipping needle, when set in vibration, to come to rest, was influenced by neighbouring non-magnetic substances. In Arago's rotation experiments the vibrations of a needle were found to be affected by water, ice, glass, charcoal, and mercury.[70]

1825—1827. Boussingault's magnetic observations in different parts of South America (Marmato, Quito).

1826—1827. Keilhau's observations of the magnetic force at twenty stations (in Finmarken, Spitzbergen, and Bear Island); and Keilhau and Boeck's observations in in South Germany and Italy (Schum. Astr. Nachr. No. 146.)

1826—1829. Lütke's Voyage of Circumnavigation. The magnetic part was drawn up with great care in 1834 by Lenz. (See Partie nautique du Voyage, 1836.)

1826—1830. Captain Philip Parker King's observations on the east and west coasts of South America (Brazil, Monte Video, Straits of Magellan, Chiloe, and Valparaiso).

1827—1839. Quételet, Etat du Magnétisme terrestre (Bruxelles) pendant douze années. Very exact observations.

1827. Sabine, Comparison of the relative intensity of the earth's magnetic force in Paris and in London. An analogous comparison of the force in Paris and at Christiania was made by Hansteen, 1825 and 1828 (British Association Reports, 1837, p. 19—23). The numerous results of French, English, and Scandinavian travellers, on the intensity of the horizontal force, were first brought into numerical connection, so as to afford relative values, by means of these two comparisons, in which intercompared needles were vibrated at the three above-named places. The relative numbers found were: for Paris, 1·348 by me; for London, 1·372 by Sabine; and for Christiania, 1·423 by Hansteen. All are relative to the intensity of the earth's magnetic force at a point of the "magnetic equator" (or line without inclination), where it intersects the Peruvian Cordillera, between Micuipampa and Caxamarca in S. latitude 7° 2′,

and W. longitude 78° 46′, and where the intensity is taken as=1·000. It was to this point (Humboldt, Recueil d'Observ. astr., T. ii. p. 382—385; and Voyage aux Régions équinox. T. iii. p. 622) that for forty years the reductions in all tables of the force were referred as a basis (Gay-Lussac, in the Mém. de la Soc. d'Arcueil, T. i. 1807, p. 21; Hansteen über den Magnetismus den Erde, 1819, S. 71; Sabine, in the Report of the British Association at Liverpool, p. 43—58.) It has since been justly objected, that the point so taken as unity does not afford an appropriate general standard, since the line of no inclination([71]) does not correspond with the points of weakest intensity in many meridians, and that no point on the earth's surface can be taken as a permanent unity, on account of secular change. (Sabine, in the Phil. Trans. for 1846, Part iii. p. 254; and in the Manual of Scientific Inquiry for the use of the British Navy, 1849, p. 17.)

1828—1829. Hansteen and Due's expedition to Siberia: magnetic observations in European Russia and Eastern Siberia, as far as Irkutzk.

1828—1830. Adolph Erman's journey through Northern Asia, and voyages in the Pacific and Atlantic Oceans in the Russian frigate Krotkoi. The identity of the instruments used, the employment of the same or similar methods throughout, the exactness of the astronomical determinations of geographical position, and the whole of the observations being made by the same thoroughly informed and practised observer, returning to the same point after having gone round the globe, are all circumstances which combine in assigning a high value to this enterprise, executed at private expense. (See the General Map of the Declination,

founded on Erman's observations, in the Report of the Committee of Physics of the Royal Society on the occasion of the Antarctic Expedition, 1840, Plate iii.)

1828—1829. Humboldt's continuation of the observations at the solstices and equinoxes with a Gambey's needle on horary variation and extraordinary perturbations, begun in 1800 and 1807 in a magnetic house built expressly for the purpose at Berlin. Corresponding determinations made at Petersburg, Nikolajeff, and in the mines at Freiberg, by Professor Reich, at 216 feet below the surface. Dove and Riess continued these observations until Nov. 1830, including both declination and intensity of the horizontal force. (Poggend. Annalen, Bd. xv. S. 318—336; Bd. xix. S. 375—391, with 16 Tables; Bd. xx. S. 545—555.)

1829—1834. The botanist David Douglas, who was killed at Owyhee by falling into a pit into which a wild bull had previously fallen, made a fine series of magnetic observations on the north-west coast of America and in the Sandwich Islands, including one station on the edge of the crater of Kiraueah (Sabine, at the British Association Meeting at Liverpool, p. 27—32).

1829. Kupffer, Voyage au Mont Elbrouz dans le Caucase (p. 68 and 115).

1829. Humboldt, observations on terrestrial magnetism, together with astronomical determinations of geographical position, on a journey by command of the Emperor Nicholas in Northern Asia, from the long. of 11° 3′ to that of 80° 12′ east of Paris, near Lake Dzaisan, and from the lat. of 45° 43′ (in the Island of Birutschicassa in the Caspian) to

58° 52′ in the northern part of the Oural Mountains at Werchoturie. (Asie centrale, T. iii. p. 440—478.)

1829. The Imperial Academy of Sciences at St. Petersburg consented to my proposition for the establishment of magnetical and meteorological stations in the most varied climatic zones of the Russian dominions in Europe and Asia, and for the erection of a physical central observatory in the capital of that empire, under the active and able direction of Professor Kupffer. (Compare Kosmos, Bd. i. S. 436—439, Anm. 36; Engl. p. 419—421, Note 166; Kupffer, Rapport adressé à l'Acad. de St.-Pétersbourg relatif à l'Observatoire physique central fondé auprès du Corps des Mines, in Schum. Astr. Nachr. No. 726; and in the Annales magnétiques, p. xi.) By the unfailing support given by Count Cancrine, the Minister of Finance, to every great scientific undertaking, it was found possible to commence a portion of the corresponding observations(72) from the Crimea to the White Sea, and from the Gulf of Finland to the shores of the Pacific in Russian America, as early as 1832. A permanent magnetic station was established in Pekin in the old convent which had been periodically inhabited by monks of the Greek Church since the time of Peter the Great. A highly informed and scientific observer, the astronomer Fuss, who had taken the chief part in the measurements for determining the difference of level between the Caspian and the Black Sea, was selected to make the first magnetic arrangements in China. Subsequently, Kupffer visited the magnetical and meteorological stations as far eastward as Nertschinsk in long. 117° 16′ east from Paris, in order to compare the instruments established at

them with the proper standards. The (no doubt) excellent observations made by Fedoroff, in Siberia, are still unpublished.

1830—1845. Colonel Graham (of the topographical engineers of the United States): observations on the magnetic force on the southern boundary of Canada. (Sabine, in the Phil. Trans. for 1846, Pt. iii. p. 242).

1830. Fuss: magnetic, astronomic, and hypsometric observations (Report of the Seventh Meeting of the Brit. Assoc 1837, p. 497—499) on a journey from Lake Baikal through Ergi Oude, Durma, and the region of Gobi (which is only about 2500 feet high), to Pekin, in order to found there the magnetical and meteorological observatory in which Kovanko has observed for ten years. (Humboldt, Asie centrale, T. i. p. 8; T. ii. p. 141; T. iii. pp. 468 and 477.)

1831—1836. Captain Fitz Roy, in a voyage of circumnavigation in the 'Beagle,' as well as in the survey of the coasts of the southern extremity of America; observations with a Gambey's Inclinatorium, and horizontal needles received from Hansteen.

1831. Dunlop, Director of the Astronomical Observatory of Paramatta: observations on a Voyage to Australia, (Phil. Trans. for 1840, Pt. i. p. 133—140).

1831. Faraday's Induction-currents, the theory of which has been extended by Nobili and Antinori; great discovery of the production of light by magnets.

1833 and 1839 are the two important epochs of the first promulgation of the theoretical views of Gauss:—1. Intensitas vis magneticæ terrestris ad mensuram absolutam revocata, 1833 (p. 3, "elementum tertium, intensitas, usque ad

tempora recentiora penitus neglectum mansit"); 2. The immortal work, Allgemeine Theorie des Erdmagnetismus, in the Resultate aus den Beobachtungen des magnetischen Vereins im Jahr 1838, herausgegeben von Gauss und Weber, 1839, S. 1—57, (General Theory of Terrestrial Magnetism, published in English in Vol. ii. of the Scientific Memoirs, p. 184—251; and Supp. Vol. ii. p. 313—317).

1833. Barlow's investigations on the attraction of ships' iron, and the means of determining its deflecting influence on the compass; examination of electro-magnetic currents in "Terellas." General Maps of the Declination. (Compare Barlow's "Essay on Magnetic Attraction," 1833, p. 89, with Poisson, "sur les déviations de la boussole produites par le fer des vaiseaux," in the Mém. de l'Institut, T. xvi. p. 481—555; Airy, in the Phil. Trans. for 1839, Pt. i. p. 167, and for 1843, Pt. ii. p. 146; Sabine, in the account of Sir James Ross's observations, in the Phil. Trans. for 1849 Pt. ii. p. 177—195.)

1833. Moser, in Poggendorff's Annalen, Bd. ii. S. 53—64, on a method of ascertaining the position and force of the variable magnetic poles.

1833. Christie on the Arctic observations of Captain Back, Phil. Trans. for 1836, Pt. ii. p. 377. See also his earlier and important Memoir in the Phil. Trans. for 1825, Pt. i. p. 23.

1834. Parrot's Reise nach dem Ararat (Journey to Mount Ararat), Magnetismus, Bd. ii. S. 33—64.

1836. Major Estcourt in Colonel Chesney's Euphrates expedition. A part of the Force observations was lost in the steamer 'Tigris,' a circumstance which is the more to be regretted because there is so entire an absence of exact

observations in this part of Western Asia, and generally south of the Caspian.

1836. Lettre de M. de Humboldt à S. A. R. le Duc de Sussex, Président de la Soc. Roy. de Londres, sur les moyens propres à perfectionner le connaissance du magnétisme terrestre par l'établissement de stations magnétiques et d'observations correspondantes (Avril, 1836). On the happy results of this application, and its influence in contributing towards the great Antarctic Expedition of Sir James Ross, see Kosmos, Bd. i. S. 438 (Engl. p. 421); and Sir James Ross's Voyage to the Southern and Antarctic Regions, 1847, Vol. i. p. xii.

1837. Sabine on the variations of the intensity of the magnetic force of the earth: British Association Reports, Liverpool Meeting, p. 1—85. This is the most complete work which has been published on this branch of the subject.

1837—1838. Establishment of a magnetic observatory at Dublin by Professor Humphry Lloyd. On the observations made there from 1840 to 1846, see Trans. of the R. I. A. Vol. xxii. Pt. i. p. 74—96.

1837. Sir David Brewster: A Treatise on Magnetism, p. 185—263.

1837—1842. Sir Edward Belcher's observations in a voyage to Singapore, the Chinese Seas, and the West Coast of America: Sabine, in the Phil. Trans. for 1843, Pt. ii. p. 113, 140, 142. The observations of the inclination viewed in connection with mine in 1803 indicate a very unequal progression in the secular change at different places. I found, for example, the inclinations at Acapulco, Guayaquil, and Callao $+38° 48'$, $+10° 42'$, and $-9° 54'$; Sir Edward Belcher, $+37° 57'$, $+9° 1'$, and $-9° 54'$. May the frequent

earthquakes on the Peruvian coast exert a local influence on the phænomena of the earth's magnetic force?

1838—1842. Wilkes's Narrative of the United States Exploring Expedition (Vol. i. p. xxi.)

1838. Lieutenant Sulivan's observations in a voyage from Falmouth to the Falkland Islands: Sabine, in the Phil. Trans. for 1840, Pt. i. p. 129, 140, and 143.

1838 and 1839. Establishment of the magnetic observatories in the two hemispheres at the cost of the British Government, and under the able direction of Colonel Sabine. The instruments were sent out in 1839; the observations began at Toronto in Canada, at Hobarton in Van Diemen Island, and at St. Helena, in 1840, and at the Cape of Good Hope in 1841. (Sir John Herschel in the Quarterly Review, Vol. lxvi. 1840, p. 297; Becquerel, Traité d'Electricité et de Magnétisme, T. vi. p. 173). By a laborious and profound investigation and treatment of the rich treasure of observations obtained from these stations, embracing all the elements or variations of the earth's magnetic activity, Colonel Sabine, as Superintendent of the Colonial Observatories, has discovered laws previously unknown, and opened new views to science. The results of his investigations have been published by him in a long series of memoirs, entitled Contributions to Terrestrial Magnetism, Nos. I. to IX. (and other detached memoirs) in the Phil. Trans. as well as in separate volumes, and constitute an essential part of the foundation of this branch of cosmical knowledge. I will name only some of the most remarkable among them. 1. Observations on days of unusual magnetic disturbance, Vol. i. 1840 to 1844 inclusive; and Phil. Trans. for 1851, Pt. i. p. 123—139.

2. Observations made at the magnetical observatory at Toronto (N. lat. 43° 39′; W. long. 79° 21′·5), Vol. i. 1840, 1841, and 1842; and Vol. ii. 1843, 1844, and 1845. 3. The very different march of the magnetic declination in the two half-years at St. Helena (S. lat. 15° 55′, W. long. 5° 41′): Phil. Trans. for 1847, Pt. i. p. 54. 4. Observations made at the magnetical and meteorological observatory at the Cape of Good Hope, 1841—1846: Vol. i. Magnetism. 5. Observations made at the magnetical and meteorological observatory at Hobarton (S. lat. 42° 52′, E. long. 147° 27′·5) in Van Diemen Island, and on the Antarctic Expedition, Vols. i., ii., and iii., 1841—1852 (on the separation of the eastern and western disturbances, see Vol. ii. p. ix.—xxxvi.) 6. Magnetic phænomena in the Antarctic circle, and in Kerguelen and Van Diemen Islands: Phil. Trans. for 1843, Pt. ii. p. 145—231. 7. On the Isoclinal and Isodynamic Lines in the Atlantic Ocean in 1837: Phil. Trans. 1840, Pt. i. p. 129—155. 8. Declination Map of the Atlantic Ocean, representing the lines of magnetic declination between 60° N. and 60° S. latitude for 1840: Phil. Trans. 1849, Pt. ii. p. 173—233. 9. On the means adopted at the British Colonial observatories for determining the absolute values, secular change, and annual variation of the magnetic force: Phil. Trans. 1850, Pt. i. p. 201—219. (Coincidence shown of the epoch of the Earth's greatest proximity to the Sun, with the greatest intensity of the terrestrial magnetic force in both hemispheres, and with the greatest amount of inclination, p. 216.) 10. On the isoclinal and isodynamic lines in the northern parts of the North American continent, and on the geographical position of the point of maximum force, deduced from the observations of

tions of Captain Lefroy: Phil. Trans. 1846, Pt. iii. p. 237—336. 11. On the periodic laws of the disturbances of the declination (magnetic storms) at Toronto in Canada, and at Hobarton in Van Diemen Island, and on the accordance of the approximately decennial period of the magnetic variations depending on the sun, with the also approximately decennial period, discovered by Schwabe of Dessau, in the phænomena of the solar spots: Phil. Trans. 1852, Pt. i. p. 121—124.

1839. Isoclinal and isodynamic lines in the British Islands, from observations of Humphry Lloyd, John Phillips, Robert Were Fox, James Ross, and Edward Sabine. In 1833, the British Association, at Cambridge, pointed out the importance of systematic observations of the inclination and force being made in different parts of the kingdom; and already, in the summer of 1834, their wish had begun to be fulfilled by Professor Lloyd and Colonel Sabine; in 1835 and 1836 the work was extended to Wales and Scotland, and in 1838 complete isoclinal and isodynamic maps of the British Islands were presented to the British Association, and published in the Report of the Meeting at Newcastle, p. 49—196.

1838—1843. The important voyages of Sir James Clark Ross towards the South Pole, equally admirable for the knowledge gained thereby of the existence of the much-doubted Antarctic lands, and for the new light thrown on the magnetic condition of very large and important portions of the earth's surface. The numerical values of the three elements of terrestrial magnetism were determined over almost two-thirds of the area of the higher latitudes of the Southern hemisphere. Sir James Ross's magnetic obser-

vations have been co-ordinated and published by Colonel Sabine in the Phil. Trans. for 1843, Art. x., and for 1844, Art. vii.; and part yet remains to be published.

1839—1851. Kreil's observations on the variations of the three magnetic elements, continued for more than twelve years at the Imperial Astronomical Observatory at Prague, and published in annual volumes, with valuable co-ordinations and discussions.

1840. Hourly magnetic observations with a Gambey's declination-needle, made during a ten years' sojourn in Chili by Claudio Gay. (See his Historia fisica y politica de Chile, 1847.)

1840—1851. Lamont, Director of the Astronomical Observatory at Munich: Results of his magnetic observations compared with those of Göttingen, which go back as far as 1835: important law of a decennial period in the diurnal variation of the declination. (Lamont, in Poggend. Ann. der Phys. 1851, Bd. lxxxiv. S. 572—582; and Relshuber, 1852, Bd. lxxxv. S. 179—184.) The already noticed conjecture of a connection between the periodical magnetic variations which follow laws depending upon solar hours (magnetic storms and diurnal variation), and the periodical "frequency of the solar spots," was first made by Col. Sabine, in the Phil. Trans. for 1852; and four or five months later, but without his having known of Colonel Sabine's published paper, by the learned Director of the Astronomical Observatory at Berne, Rudolph Wolf, in the Schriften der schweizerischen Naturforscher.(73) Lamont's Handbuch des Erdmagnetismus (1848) contains an account of the most recent German apparatus and methods of computing the results of observation.

1840—1845. Bache, Director of the Coast Survey of the United States: Observations made at the Magnetical and Meteorological Observatory at Girard's College (Philadelphia), published 1847.

1840—1842. Lieutenant Gilliss (U.S.): Magnetical and meteorological observations made at Washington, published 1847 (p. 2—319; magnetic storms, p. 336).

1841—1843. Sir Robert Schomburgk: Declination observations in the forest region of Guyana between Mount Roraima and the village of Pirara, between the parallels of 4° 57′ and 3° 39′. (Sabine, in the Phil. Trans. for 1849, Part ii. p. 217.)

1841—1845. Magnetical and meteorological observations made at Madras.

1843—1844. Magnetic observations at Sir Thomas Brisbane's observatory at Makerstoun (Roxburghshire, Scotland), in latitude 55° 34′. (See Transact. of the Royal Society of Edinburgh, Vol. xvii. Part ii. p. 188; and Vol. xviii. p. 46.)

1843—1849. Kreil on the influence of the Alps on the manifestations of the terrestrial magnetic force. (Compare Schum. Astr. Nachr. No. 602.)

1844—1845. Expedition of the 'Pagoda' to high Antarctic latitudes (64°—67°), E. longitude 2° to 115°, embracing all the three elements of terrestrial magnetism, under the command of Lieut. Moore, R.N., who had previously been employed in the Antarctic Expedition; the observations being made jointly by him and Lieut. Clerk, of the Royal Artillery, who had previously directed the magnetic observatory at the Cape of Good Hope;—a worthy completion of the Antarctic labours of Sir James Clark Ross. (Sabine, in Phil. Trans. 1846).

1845. Proceedings of the Magnetical and Meteorological Conference held at Cambridge.

1845. Observations made at the Magnetical and Meteorological Observatory at Bombay, under the superintendence of A. B. Orlebar. The observatory was built in 1841, on the little island of Colaba.

1845—1850. Six volumes of Results of the Magnetical and Meteorological Observations made at the Royal Observatory at Greenwich. The magnetic observatory was built in 1838.

1845. Simonoff, Prof. at Kazan : Recherches sur l'Action magnétique de la Terre.

1846—1849. Captain Elliot (Madras Engineers) : Magnetic Survey of the Eastern Archipelago, sixteen stations, several months being passed at each, in Borneo, Celebes, Sumatra, the Nicobar, and the Keeling Islands, and extending between N. latitude 16° and S. latitude 12°, longitudes 80° and 125° E. (Phil. Trans. for 1851, Part i. p. 287—331, and p. l.—clvii.) There are appended maps of the lines of equal inclination and declination, as well as of the horizontal and total force. This work, which also represents the positions of the magnetic equator, or line of no inclination, and of the line of no declination, is one of the most remarkable and comprehensive of modern times.

1845—1850. Faraday's brilliant physical discoveries : 1. On axial (paramagnetic) and equatorial (diamagnetic) direction assumed by different bodies when freely suspended and placed under external magnetic influences.(74) (Phil. Trans. for 1846, § 2420 ; and Phil. Trans. for 1851, § 2718—2796) ; 2. On the relation of electro-

magnetism to a polarised ray of light, and the rotation of the polarised ray under the intervention of an altered molecolar condition of the substance which is made the conducting medium both of the ray and of the magnetic current (Phil. Trans. for 1846, § 2195 and 2215—2221); 3. On the remarkable property possessed by oxygen gas (the only one of the gases which is paramagnetic) similar to that possessed by soft iron only in a much weaker degree, of assuming polarity under the inducing influence of the earth, as soft iron does in the presence of a permanent magnet(75). (Phil. Trans. 1851, § 2297—2967.)

1849. Professor William Thompson, of Glasgow: A mathematical theory of magnetism, Phil. Trans. for 1851, Part i. p. 243—285. (On the problem of the distribution of the magnetic force, compare § 42 and 56, with Poisson, in the Mém. de l'Institut, 1811, Part i. p. 1; Part ii. p. 163.)

1850. Airy on the present state and prospects of the science of terrestrial magnetism, a fragment of a very promising essay.

1852. Kreil, Influence of the Moon on the magnetic declination at Prague in the years 1839—1849. On the earlier labours of this exact observer, and on his first conjectures regarding the lunar influence, see Osservazioni sull' intensità e sulla direzione della forza magnetica istituite negli anni 1836—1838, all' I. R. Osservatorio di Milano, p. 171; and his Mag. und Met. Beobachtungen zu Prag, Bd. i. S. 59.

1853. Faraday on lines of magnetic force, and their definite character.

1853. Sabine: on the lunar diurnal variation of the

Declination at Toronto, St. Helena, and Hobarton. (Phil. Trans. 1853.)

1853—1854. Sabine's new proofs from the observations at Toronto, Hobarton, St. Helena, and the Cape of Good Hope (from 1841 to 1851), of the character of the annual variation superimposed upon the mean diurnal variation of the Declination, and of the correspondence of its semi-annual epochs with those of the Sun's passage of the Equator. (Toronto Observations, Vol. ii. p. xxii.; and Proceedings of the Royal Society of London, May 1854.)

The preceding chronological enumeration of the advances which have been made in our knowledge of terrestrial magnetism in the course of the last half-century (during which I have myself uninterruptedly devoted the warmest interest to the subject) shows that they have had a two-fold character. The most considerable portion of these labours is that which has been devoted to the *observation* of the manifestations of the earth's magnetic activity, and to their variations according to time and place; the smaller portion has been given to *experiments*, or to the calling forth of phænomena promising to conduct us to a comprehension of the essential nature of the activity so manifested. These two lines of research,—on the one hand, that of observation of the manifestations of terrestrial magnetism (in direction and force), and on the other, that of physical experimentation on magnetic force in general,—have acted and reacted on each other, and have concurrently animated and carried forward our knowledge of Nature. Observation alone,—independent of any hypothesis on the causal connection of the phænomena, or on the *as yet* immeasurable and

unsearchable reciprocal action of molecules in the interior of substances,—has led to important numerical laws; and the admirable sagacity of experimenting physicists has succeeded in discovering, in solid and gaseous substances, previously wholly unsuspected polar properties peculiarly connected with temperature and with atmospheric pressure. Important and undoubted as are these discoveries, they cannot, in the present state of our knowledge, be yet regarded as affording satisfactory bases of explanation of the laws derived from the observations of the terrestrial magnetic phænomena. The surest means of exhausting the measurable variations as respects space, and of enlarging and completing the mathematical theory of terrestrial magnetism, so grandly sketched by Gauss, is to prosecute continuously successive determinations of the three magnetic elements at well-chosen points of the globe, each such determination referring to a definite epoch. The anticipations which I have myself formed of the great results which will follow hereafter from the combination of experiment with mathematical reasoning, have been already touched upon in the earlier pages of the present volume.(76)

We look in all the physical phænomena which take place on our planet, for cosmical connection. The word Planet of itself leads us to dependence on a central body, and to connection with a group of heavenly bodies of very various magnitudes, probably having all the same origin. The influence of the Sun's position in the heavens on the manifestation of the Earth's magnetic force was very early recognised;—most clearly, in the discovery of an horary variation in the declination of the needle; more obscurely, in the conjecture formed by Kepler, a century before, of the

axes of all the planets being directed towards the same quarter. Kepler said expressly, "that the sun may be a magnetic body, and that the force which moves the planets may therefore reside in the sun." (77) Mass-attraction and gravitation appear here under the symbol of magnetic attraction. Horrebow,(78) who did not confound gravitation with magnetism, was the first who termed the solar light "a perpetual Aurora in the sun's atmosphere, produced by magnetic forces." In more modern times (and the difference is important), the views which have been formed respecting the *modus operandi* of the sun's action have diverged into two distinct classes.

It has been considered either that the sun, without being itself magnetic, acts on the magnetism of the earth solely through the medium of its effects in causing variations of temperature (this has been the view entertained by Canton, Ampère, Christie, Lloyd, and Airy),—or, as supposed by Coulomb, that the sun being enveloped in a magnetic atmosphere(79) influences the magnetism of the earth by direct action. Faraday's striking discovery of the paramagnetic property of oxygen would indeed remove one great difficulty opposing the first-named view, *i. e.* the difficulty of supposing with Canton that the sea and the solid crust of the earth have their temperature instantaneously and considerably raised by the passage of the sun over the meridian of the place; but on the other hand, Colonel Sabine's very extensive combination and sagacious discussion of all the facts of observation have led to the result, that the periodical variations in the earth's magnetic activity do not correspond to, and therefore cannot be assumed to be caused by, the periodic variations of temperature which take place within the

part of the atmosphere accessible to our observation. Neither the principal epochs of the diurnal and annual variations of the declination (the annual have been accurately represented for the first time by Sabine from a vast body of observations), nor the periods of the mean intensity of the earth's force,(80) agree with the periods of maxima or minima in the temperature either of the atmosphere or of the earth's outer crust. The turning-points in the most important magnetic phænomena are the solstices and the equinoxes.

The epoch at which *in both hemispheres* the intensity of the earth's force is greatest, and the direction of the dipping-needle is most nearly vertical, is that of the greatest proximity of the Earth to the Sun,(81) when also the Earth has the greatest velocity in its movement of translation in its orbit. But at the period of perihelion (December, January, and February), and at that of aphelion (May, June, and July), the circumstances of temperature in the two hemispheres, northern and southern, are diametrically opposed to each other: it follows, therefore, that the turning-points, or change from decreasing to increasing magnetic force, and *vice-versâ,* cannot be ascribed to the sun as the source of heat.

Annual mean values derived from the observations at Munich and Göttingen have led the active director of the Royal Bavarian Observatory, Lamont, to infer the remarkable law of a variation-period of $10\frac{1}{3}$ years in the amount of the mean diurnal variation of the magnetic declination in different years.(82) In a series lasting from 1841 to 1850, the monthly means of the variations of the declination attained their minimum in $1843\frac{1}{2}$ and their maximum in

$1848\frac{1}{2}$, and this in a very regular manner. Without his being aware of these results, the comparison of the monthly means of the same years, 1843—1848, derived from observations taken at places separated from each other by almost an entire diameter of the globe (Toronto in Canada, and Hobarton in Van Diemen Island), had led Colonel Sabine to infer the existence of a similar variation-period in the frequency and amount of the magnetic disturbances or storms. He suggested that a purely cosmical cause might be found in the perturbations observed to take place in the sun's atmosphere with a frequency varying according to the same approximately decennial period.(83) Schwabe, the most diligent observer of the solar spots among astronomers now living, had found (as I have related in a preceding volume), (84) in a long series of years, from 1826 to 1850, a periodical variation in the frequency of the spots, the maxima falling in the years 1828, 1837, and 1848; and the minima in the years 1833 and 1843. "I have not," he adds, "had the opportunity of examining a continuous series of older observations, but I willingly subscribe to the opinion that this period may itself be a variable one." An analogy to such "periods within periods" as are here supposed, is presented to us in the luminous processes of other self-luminous celestial bodies or suns, as in the very complicated periodicity of the variations in the light of β Lyræ and Mira Ceti, investigated by Goodricke and Argelander.(85)

If we consider with Sabine, that the magnetism of the Sun manifests itself in the increased magnetic force of the Earth at the time of her perihelion (*i. e.* when she is nearest to the Sun), we may be the more surprised that, according

to Kreil's extensive investigation of the Moon's magnetic influence no sensible difference according to the varying phases of the Moon, or to her different distances from the Earth, has yet been found. It would seem as if the near proximity of the Moon, as compared with the Sun, does not compensate for the smallness of her mass. The principal result[86] of the examination which has been made into the magnetic influence of our satellite, which, according to Melloni, shows only a faint trace of thermal influence, is that the magnetic declination observed at the surface of our globe undergoes, in the course of a lunar day, a regular variation, attaining two maxima and two minima. Kreil remarks very justly, that "if the Moon produces at the surface of the Earth no sensible increase of temperature" (*i. e.* no increase cognisable by our ordinary thermometers), "she cannot produce any variation in the Earth's magnetic force by thermal agency; and if, therefore, we do, nevertheless, find such a variation, we must conclude that it is produced by some mode of action other than thermal." In all actions which do not present themselves at once as the unmistakable results of a single cause, we can only, as here in the case of the Moon, recognise their independent existence after carefully excluding, or eliminating, many extraneous disturbing elements.

But although at the present time the magnetic variations of largest amount, and of most decided character, are not, it must be admitted, satisfactorily explained by the maxima and minima of the variations of temperature, it is yet scarcely possible to doubt that when, at some future but not distant period, there shall be a more complete and deeper insight into the whole process of magnetic action, the great

discovery of the polar properties of the oxygen of the atmosphere which surrounds our globe will present an element in the explanation which shall then be given of the genesis of that process. It is hardly conceivable that in the harmonious concurrent action of all natural forces this property of oxygen, and its modification by changes of temperature, should have no share in calling forth magnetic phænomena. If, in accordance with the conjecture expressed by Newton, the substances belonging to the same planetary system are, in all probability, for the most part the same,(87) we may also be led, by inductive reasoning, to surmise that the endowment of gravitating matter with electro-magnetic activity is not confined to our own globe. To assume the contrary, would be to impose arbitrarily dogmatic limits on cosmical views. Coulomb's hypothesis respecting the influence of the magnetic sun on the magnetic earth is certainly not opposed to any analogy furnished by the knowledge we have as yet acquired.

If we now pass to the purely objective representation of the magnetic phænomena presented to us by the Earth, at the different parts of its surface, and in its different positions relatively to the Sun, we must distinguish, in the numerical results of observation, the variations which are included within short periods, from those which extend over very long periods. All are intermingled and intersecting, like circles of undulation in fluids to which a movement is given, sometimes reinforcing, and sometimes partially or wholly compensating and destroying each other.

In the *geographical* distribution of the phænomena, there present themselves more particularly to our notice:—

Two magnetic poles, one in each hemisphere, at unequal distances from the earth's poles of rotation : these are points on the earth's surface at which the magnetic inclination is 90°, and at which, therefore, the horizontal force vanishes.

The magnetic equator: *i. e.* the curve or line encompassing the earth, on which the inclination of the needle is 0°.

Lines of equal declination, and on which the declination of the needle is 0° (isogonic lines, and lines of no declination).

Lines of equal inclination (isoclinal lines).

Four points of greatest intensity of the earth's magnetic force; two, of unequal strength, in each hemisphere.

Lines of equal terrestrial magnetic force (isodynamic lines).

The undulating line which connects those points at which the force is weakest in each meridian, and which has, on that account, been termed a "dynamic equator," or "equator of force." (88) It does not coincide either with the geographical or the magnetical equator.

The boundaries of the zone (generally of very weak magnetic force), in which the horary (or diurnal) variations of the needle at certain hours of the day conform, during one part of the year to the diurnal variation of the phænomena in the northern, and during the other part of the year to those of the southern, magnetic hemisphere;(89) taking part, therefore, alternately in the variations of both hemispheres.

In this enumeration I have reserved the word "pole"

exclusively for the two points on the earth's surface at which the horizontal force vanishes; because (as has been already remarked) these points, in which the maxima of force are *not* situated, have occasionally, in modern times, been confounded with the four points of maximum intensity of the earth's force.(90) Gauss has also shown that it is objectionable to give the name of "magnetic axis of the earth" to the cord connecting the points above-named, at which the inclination of the needle at the surface of the globe is 90°.(91) The various points and lines which have been thus noticed are so connected with each other, that we are enabled to describe the complicated phænomena of terrestrial magnetism under three heads only, or as belonging to three "elements" or manifestations of one and the same activity, or force; termed respectively,—magnetic "force," "inclination," and "declination."

Intensity of the Magnetic Force.

The recognition and examination of this, the most important element of terrestrial magnetism, by the direct measurement of the strength of the total force, did not follow, until after considerable delay, the recognition and examination of the *direction* of the same force measured in the horizontal and vertical planes (declination and inclination). Experiments in which a magnetic needle is made to vibrate for the purpose of inferring from the duration of the vibrations the intensity of the magnetic force, were first brought into use towards the close of the last century: during the present century they have been constantly and earnestly prosecuted. Graham, in 1723, measured the

vibrations of his dipping-needle, with the view of examining whether they were constant,(92) and of ascertaining the ratio of the directive force to the force of gravity. The first attempt to determine, by the number of vibrations performed in equal times, the comparative force of magnetism at points of the earth distant from each other, was made by Mallet, in 1769. With very imperfect instruments, he found no difference in the number of vibrations performed in the same interval of time at St. Petersburg in lat. 59° 56′, and at Ponoi, in lat. 67° 4′,(93) whence arose the erroneous opinion, which continued to the time of Cavendish, that the intensity of the earth's magnetic force is the same in all latitudes. Borda, indeed, as he has often related to me, on theoretical grounds never shared in this error, nor did Le Monnier; but Borda himself, in his expedition to the Canaries in 1776, was prevented by the imperfection of his dipping-needle (friction on its pivots) from discovering any differences of magnetic force at places distributed over an interval of 35° of latitude,—Paris, Toulon, Santa Cruz in Teneriffe, and Goree (Voyage de la Pérouse, Vol. i. p. 162). By the aid of improved instruments, these differences were found for the first time in the ill-fated expedition of La Pérouse, in the years 1785 and 1787, by Lamanon, and were communicated by him from Macao to the Secretary of the Paris Academy; but, as I have already remarked (p. 63), they remained till a much later period, unnoticed, and buried in the Archives of the Academy.

The first published observations of the variation of the force (which were also begun at Borda's request) were my own, made in my travels to the equinoctial regions of

America in the years 1798—1804. Still earlier results on the earth's magnetic force had been obtained by my friend De Rossel in 1791 and 1794 in the Indian Seas, but they were not printed until four years after my return from Mexico. In 1829 I had the advantage of being enabled to add to my determinations of the magnetic force and inclination, so as to make them extend over 188° of longitude (or more than half the circumference of the globe), viz. from the shores of the Pacific Ocean eastward to the Siberian frontier of the Chinese territories, two-thirds of the interval being across the interior of continents. The differences of latitude were from 60° N. to 12° S., or 72°.

If, in examining the distribution of the magnetic force over the surface of the earth, we consider carefully the direction of the successive isodynamic lines (or curves of equal magnetic force) enclosing each other, and proceed from the outer or weakest force to the inner curves of successively stronger force, we find in each hemisphere, at very unequal distances both from the poles of the earth and the magnetic poles, two points, or, as they have been called, "foci," of maximum force, one stronger and the other weaker. Of these four points on the earth's surface, we find, taking the northern hemisphere first,(94) the strongest (the American focus) in lat. 52° 19′, and long. 91°·58 W.; and the weaker (often termed the Siberian focus) in lat. 70° N., long. 120° E., or perhaps a few degrees less easterly. Erman, in 1829, in travelling from Parchinsk to Iakutzk, found the curve of greatest intensity (1·742) near Beresowski Ostrow, in long. 117° 53′ E., lat. 59° 44′ N.); Erman, Magnet. Beob. S. 172 and 540; Sabine, in the Phil. Trans. for 1850 (Pt. i. p. 218). Of these two determinations, that of the

American focus is the more secure, particularly in respect to latitude: "the longitude," it is said, "is probably rather too westerly;" it places the oval which encloses the stronger of the two northern foci in the meridian of the western end of Lake Superior. We are indebted for this determination to the important land expedition in 1843 of Captain Lefroy, of the British Royal Artillery, formerly Director of the St. Helena, and since of the Toronto, Magnetic Observatory. "The junction of the two loops of the lemniscate appears to be situated north-east of Behring's Straits, somewhat nearer to the Asiatic than to the American focus."

When, in 1802, on the Peruvian chain of the Andes (between Micuipampa and Caxamarca, in lat. 7° 2 S. and long. 81° 8′ W. from Paris), I intersected the magnetic equator or line on which the inclination is 0, and when I found the magnetic force increase as I proceeded either to the north or to the south from this remarkable spot,—there being at that time, and long afterwards, an entire absence of all other points of comparison,—I was led by an erroneous generalisation of these, the only data which observation then presented, to believe that the earth's magnetic force would be found to increase continuously from the magnetic equator to each of the magnetic poles, or points of 90° inclination, which I thought were probably also the points of greatest terrestrial magnetic force. When we come for the first time on the trace of a great natural law, the views first taken almost always require some subsequent rectification. Sabine([95]) has shown, by his own observations (made through an extensive range of latitude, in the years 1818 to 1822), and by a careful combination of these with those of many other observers (experiments of vibration with vertical

and horizontal needles having become more and more general), that the magnetic force and the inclination undergo very dissimilar modifications,—that the minimum of force is in many places considerably distant from the line of no dip; and even, that in the northern part of Canada and the Hudson Bay territories, in the meridian of about 92° or 93° W. long., the intensity of the magnetic force, instead of increasing, decreases from about the lat. of 52° to the magnetic pole in lat. 70°. At the Canadian focus of greatest magnetic force in the northern hemisphere, determined from Lefroy's observations, the inclination of the needle, in 1845, was only 73° 7′, and in both hemispheres the maxima of magnetic force are found associated with inclinations much less than 90°.([96])

Excellent and abundant as are the observations of magnetic force which we owe to the expeditions of Sir James Ross, and Captains Moore and Clerk, in the Antarctic Seas, yet there still remains much doubt respecting the positions of the stronger and the weaker focus in the southern hemisphere. James Ross crossed the isodynamic curves of highest value in several places, and after a careful discussion of his observations Sabine places the one focus about the lat. of 64° S., long. 137° 30′ E. Ross himself, in the narrative of his great voyage,([97]) supposes the one focus to be in the vicinity of the Terre Adélie discovered by D'Urville, or in about lat. 67° S., long. 140° E. He thought he was approaching the other focus in 60° S. lat., and 125° W. long.; but was afterwards inclined to place it considerably farther to the south, nearer the magnetic pole, and therefore in a more easterly meridian.([38])

After assigning the positions of the four maxima of magnetic force, it remains to give the ratio of their respective degrees of intensity. These are stated either according to the old relative and arbitrary scale which has been so often alluded to, *i. e.* by comparison with the intensity found by me at the above-mentioned point of the magnetic equator in lat. 7° 2′ S., and long. 81° 8′ W. from Paris,—or in absolute measure, as first proposed by Poisson and Gauss(99). In the relative scale in which the force observed by me on the magnetic equator is taken as =1·000, the magnetic force in Paris and in London, (employing the determination of the ratio of the force in Paris to that in London made in 1827, and mentioned in p. 71 of the present volume), is 1·348 in Paris, and 1·372 in London. These numbers converted into the absolute scale would be about 10·20 and 10·38; and the force observed by me in Peru, and taken as =1·000 in the arbitrary scale, would be, according to Sabine, 7·57; this is higher, therefore, than the force at St. Helena, which is 6·4 in the same absolute scale. All these numbers have still to undergo further alterations on account of the different years in which the comparisons were made: in both scales, the relative or arbitrary, and the absolute (the latter being the preferable scale), the above data are to be regarded simply as provisional; but even with their present imperfect degree of exactness they cast a clear light on the distribution of the terrestrial magnetic force,—an element concerning which, half a century ago, the most entire ignorance prevailed. They have also the very great cosmical value of presenting historic points of commencement from whence to date those

changes which future centuries shall manifest,—changes depending, it may be, on the influence produced by the magnetic force of the sun on the magnetism of the earth.

In the northern hemisphere the determination of the force at the strongest or Canadian focus (lat. 52° 19′, long. 92° W.), by Lefroy, is the most satisfactory. It is expressed in the relative scale by 1·878, the force in London being 1·372; and in the absolute scale by 14·21(100). Even so far south as New York, in lat. 40° 42′, Sabine had found the magnetic force not much less than at the maximum, viz. 1·803. At the weaker northern focus, the Siberian one (lat. ? 70°, long. 120° E.), the force was found, in the relative scale, by Erman, 1·74, and by Hansteen, 1·76; or, expressed in absolute measure, 13·3. The Antarctic Expedition of Sir James Ross has taught us, that the difference of force between the two foci of the southern hemisphere is probably less than between the two foci of the northern hemisphere; and that the intensity of the force is itself greater at each of the southern foci than at either of the northern foci. The intensity of the force at the stronger southern focus (lat. 64° S., long. 137° 30′ E.) is in the relative scale at least 2·06, (101) in the absolute scale 15·60: at the weaker southern focus,(102) lat. 60° S., long. ? 125° W., still, according to Sir James Ross, it is in the relative scale 1·96, and in the absolute 14·90. The greater or less distance apart of the two foci in the same hemisphere is recognised as an important element of their individual strength and of the whole distribution of the magnetic force at the surface of the earth. "Although the foci of the southern hemisphere present a strikingly greater magnetic force (in absolute measure 15·60 and 14·90) than those of

the northern hemisphere (14·21 and 13·30), yet the magnetic force of the one hemisphere is not to be regarded as greater on the whole than that of the other."

It is quite otherwise, however, if we divide the earth into an *eastern* and a *western* hemisphere by a great circle formed by the meridians of 100° and 280° E. long., so that the eastern (and the more continental) hemisphere shall comprehend South America, the Atlantic Ocean, Europe, Africa, and Asia almost to Lake Baikal; and the western (which is the more oceanic and insular) shall contain almost the whole of North America, the Pacific Ocean, New Holland, and the eastern part of Asia. These meridians are, the one about 4° west of Singapore, the other 13° west of Cape Horn; the latter being also the meridian of Guayaquil. In this division all four foci of maximum magnetic force, and even the two magnetic poles themselves, all belong to the western and more oceanic hemisphere.(103)

Adolph Erman's important observation of the least or minimum magnetic force in the Atlantic Ocean, on the east side of the Province of Espiritu Santo in Brazil (lat. 20° S., long. 35° 02′ W.), has been already referred to in Vol. i.(104). He found in the relative scale 0·706; in the absolute, 5·35. This region of weakest intensity was also crossed twice by the Antarctic Expedition of Sir James Ross,(105) between latitudes 19° and 21° S., and by Lieutenant Sulivan and Mr. Dunlop, on the passage from England to the Falkland Islands.(106) Sabine has represented the curve of least magnetic force [corresponding to the year 1840], which Ross terms "the equator of least intensity," on the isodynamic map of the whole Atlantic Ocean, drawing it from shore to shore. It cuts the west coast of Africa

at the Portuguese colony of Mossamedes (lat. 15° S.), has its concave summit in the middle of the ocean in long. 18° W., and touches the Brazilian coast in 20° S. lat. Future observations will show more clearly whether there may not also be a region of comparatively weak magnetic force (0·97 of the arbitrary scale) to the north of the equator in 10° to 12° N. lat., and about 20° to the east of the Philippines.

According to the data at present possessed, I believe I have little to alter in the ratio given in Vol. I. of the weakest to the strongest terrestrial magnetic force. It falls between 1 : 2½ and 1 : 3, but nearest to the latter; some diversity of statement being caused by alterations having been rather arbitrarily made, sometimes in the minima only, and sometimes in both minima and maxima at once.(107) Sabine(108) has the great merit of having first called attention to the importance of the "dynamic equator," (the curve of least intensity of the magnetic force). "This curve, which undulates in its progress round the globe, connects the points in each geographical meridian at which the earth's magnetic force is least, the force increasing everywhere in receding from it on either side towards the higher latitudes of the two hemispheres. It marks the physical separation between the two magnetic hemispheres more decidedly than does the line of no dip, on which the direction of the magnetic force is perpendicular to the direction of *gravity*. For the theory of magnetism all that relates to the *force* has a more immediate bearing than what relates to the *direction* of the needle, either in the horizontal or vertical plane; those planes, although necessarily used by us both in observation and discussion, not having in themselves any direct relation to magnetism. The inflexions of the

dynamic equator are complex, because they depend on forces which have four points or foci of greatest intensity which are unsymmetrically distributed on the surface of the globe, and are of unequal strength. The most remarkable of these inflections is the great convexity towards the southern pole, in the Atlantic Ocean, between the coast of Brazil and the Cape of Good Hope."

Does the intensity of the terrestrial magnetic force diminish sensibly at accessible distances above the surface of the earth? or increase sensibly in descending below that surface? The problem which these questions propose for solution is an exceedingly complicated one, in so far as it has to be determined by observations made above or below the ordinary level of the earth's surface. In attempting to solve it by means of mountain journeys or descents into mines, the facts that the upper and lower stations of observation are seldom situated vertically in respect to each other,—that the observations are frequently influenced by the character of the rocks and the presence perhaps of hidden mineral veins,—and that the fluctuations, regular or irregular, of the magnetic force itself, where the observations are not strictly simultaneous, require to be allowed for;—are all circumstances which are likely to affect the results([108]), and to cause to be ascribed to differences of height or depth what may be by no means due to them. Among the numerous mines which I have visited, descending to considerable depths, in Europe, Peru, Mexico, and Siberia, I have never found localities which were suited to inspire me with confidence in reference to this question:([109]) it must also be remembered, that considering the normal plane to be that of the level of the sea (viewed as the mean general surface of the terrestrial spheroid), many mines, though offering considerable depths below the surface of the

ground, never can reach the sea-level. Thus the works in the Joachimsthal, in Bohemia, have reached 2000 feet of absolute descent, but the lowest part is still 250 feet above the sea.([110]) Aërostatic ascents offer very different and far more favourable conditions. Gay-Lussac ascended to 21600 French feet above Paris, a height eleven times greater than the greatest *depth* attained in Europe, (speaking even merely of depth beneath the surface of the ground, without reference to the level of the sea). The results of my own mountain observations between the years 1799 and 1806 led me on the whole to regard a decrease of force in ascending as *probable*, although, (perhaps from the perturbing causes above alluded to), several amongst them gave indications of a contrary character. I have placed together in a note,([111]) data obtained by me in the course of 125 determinations of magnetic force in the chain of the Andes, in the Alps, and in Italy and Germany. My observations extended from the level of the sea to the limits of perpetual snow, and to a height of 14960 French, or 15944 English, feet; but the greatest elevations did not give the most assured results. The most satisfactory among them are afforded by the steep declivity of the Silla de Caracas, 8100 French feet above the closely-adjacent coast of La Guayra; the Santuario de N[tra] S[ra] de Guadelupe, on the summit of a limestone cliff rising immediately above the town of Bogota, giving a difference of elevation of 2000 feet; and the volcano of Purace, 8200 French feet above the Plaza Mayor of the town of Popayan. Kupffer([112]) in the Caucasus, Forbes in many parts of Europe, Laugier and Mauvais on the Canigou, Bravais and Martins on the Faulhorn, and in their adventurous sojourn very near the summit of Mont Blanc, have

indeed all remarked a decrease of magnetic force with increasing elevation. It would seem, from the general discussion by Bravais, as if the decrease were greater in the Pyrenees than in the Alps.(113)

Quételet's entirely opposite results, obtained in a journey from Geneva to the Col de Balme and the great St. Bernard, render it doubly desirable that in order to obtain a finally decisive reply to so important a question, recourse should be had to the only effectual means, *i.e.* balloon ascents, in which the surface of the earth is quitted altogether, (a step taken so long ago as 1804, by Gay-Lussac, first conjointly with Biot on the 24th of August, and then alone on the 16th of September), and that a consecutive series of experiments should be thus made. The time of vibration of needles carried in aëronautic ascents to elevations of eighteen or twenty thousand feet and upwards, can only be made to afford just inferences respecting the degree of the earth's magnetic force propagated through the free atmosphere, when the temperature correction of the needles employed is determined with great precision both before and after the ascent. The neglect of any such correction caused it to be erroneously inferred from Gay-Lussac's experiments that the magnetic force remains unaltered to an elevation of 21600 feet;(114) whereas the experiment really went to indicate the decrease of the force, since the colder temperature of the higher region must be supposed to have acted in accelerating the vibrations of the needle.(115) Neither ought Faraday's brilliant discovery of the paramagnetic force of oxygen to be left out of view in considering the subject before us. That great physicist calls attention to the consideration, that the cause of the diminution of the

magnetic force in the higher strata of the atmosphere should not be looked for solely in the increased distance from the source of the force, the solid terrestrial globe,—but may with no less probability be sought in the exceedingly rarefied state of the air at those elevations, whereby the quantity of oxygen contained in a cubic foot of atmospheric air is much less than at the surface of the earth. It appears to me that we should not be justified in extending this supposition further, than to say that the diminishing paramagnetic property of the oxygen with increased rarefaction of the air, at increased elevations, may be a concurrent modifying cause of the phænomenon in question. Modifications of temperature and of density, by the action of ascending aërial currents, will, again, modify the measure of this concurrent action ;(116) and disturbing influences thus assuming a variable and local character, will act in the atmosphere as do the different kinds of rock at the surface of the earth. At every cheering step in advance towards the better knowledge of the constituents of the gaseous envelope of our planet, and their physical properties, we become aware of fresh liabilities to error amidst the varying concurrent action of forces, and are admonished thereby of the need of still greater caution in arriving at conclusions.

The intensity of the earth's magnetic force measured at determinate points of the earth's surface, has (like all the other phænomena of terrestrial magnetism) its hourly, and also its secular variations. The former were distinctly recognised in Parry's third voyage, by that distinguished navigator, and by Lieutenant Foster, in 1825, at Port Bowen. In the middle latitudes the increase of the intensity of the magnetic force from the morning to the evening

had been the subject of very careful examination by Christie,(117) Arago, Hansteen, Gauss, and Kupffer. But as, notwithstanding the great improvements in the construction of dipping-needles, their time of vibration in the vertical plane could not be ascertained with the same accuracy as that of needles vibrating in the horizontal plane, a knowledge of the horary variations of the total force could not be obtained from the latter, without a more exact knowledge of the horary variations of the *inclination* than could be gained by the instrumental means in use before the existence of the magnetic observatories. The establishment of magnetic stations in the northern and southern hemispheres has since afforded the great advantage of supplying results at once the most numerous and the best assured, with magnetometers measuring the horary variations of the horizontal and vertical components of the force, and thus enabling their theoretical equivalents, the horary variations of the inclination and of the total force, to be learnt. It will be sufficient here to consider two of these stations,(118) both extra-tropical, and situated at nearly equal distances on either side of the equator; viz. Toronto in Canada, in 43° 32′ N. lat., and Hobarton in Van Diemen Island in 42° 53′ S. lat.; their difference of longitude being about 15 hours. In the simultaneous system of hourly observations, the observations of the winter months of the one station are made during the summer of the other, and the greater part of the night observations at the one correspond in like manner to the day observations at the other. The declination is at Toronto 1° 33′ W., and at Hobarton 9° 57′ E.; the inclination and force at the two stations are very similar, the

dip of the north end of the needle at Toronto being 75° 15′, and that of the south end at Hobarton 70° 34′,—and the total force in absolute measure 13·90 at Toronto, and 13·56 at Hobarton. Of these two so well-chosen stations, the Canadian shows, according to Sabine's investigation,(119) four, and that of Van Diemen Island only two, turning-points in the diurnal variation of the total force. At Toronto there appears to be a principal maximum at 5 h., and a principal minimum between 15 h. and 16 h.; with a weaker secondary maximum varying in different months from 18 h. to 20 h., and a weaker secondary minimum at 22 h. or 23 h. At Hobarton, on the other hand, the intensity of the force follows a single progression from a maximum between 5 h. and 6 h. to a minimum between 20 h. and 21 h.; although the inclination at that station has, as at Toronto, four turning-points.(120) By combining the variations of inclination with those of the horizontal force, Sabine has found that at both stations the total force is greatest from October to February, and least from April to August; October to February being months of winter at Toronto, and of summer at Hobarton; and April to August being months of summer at Toronto and winter at Hobarton. He thence infers that it is not to differences of temperature that we should ascribe these variations, and suggests that the increase of the total magnetic force in both hemispheres during the months when the Sun is in the southern signs, may be caused by the greater proximity of the Earth in that portion of her orbit to the Sun acting as a magnetic body.(121) At Hobarton, the intensity of the force is in the summer of that station in absolute measure 13·574, and in winter 13·543. The secular change of the total magnetic force rests as yet on

the observations of very few years. The comparison of my results with those of Rudberg, in the years 1806 and 1832, would indicate for Berlin a small decrease.(122)

Inclination.

We are indebted for the knowledge we possess of the geographical position of both the magnetic poles where the Inclination is 90°, to the observations and scientific activity of one and the same adventurous navigator, Sir James Ross: in the north, in the second expedition(123) of his uncle Sir John Ross, (1829 to 1833), and in the south in the Antarctic expedition commanded by himself (1839—1843). According to his observations, the northern magnetic pole (in 70° 5′ N. lat., 96° 43′ W. long.) is five degrees of latitude further from the pole of the earth than the southern (75° 5′ S. lat., 154° 10′ E. long.); and the difference of longitude between the two magnetic poles is 109°. The northern pole is situated on the large island of Boothia Felix (very near the American continent), a part of which had been previously called by Captain Parry, North Somerset. The observations of Sir James Ross place the pole, at the date referred to, at a short distance from the western coast of Boothia Felix, not far from Cape Adelaide, which projects between King William's Sea and Victoria Strait.(124) The south magnetic pole has not been, like the northern one, directly reached. On the 17th of February, 1841, Sir James Ross in the 'Erebus,' attained 76° 12′ S. lat. in the meridian of 163° 02′ E. long., but the magnetic inclination did not exceed 88° 40′, so that the south magnetic pole was supposed to be still 160 English nautical miles distant.(125) Numerous and very exact observations of declination, (determining the

intersection of the magnetic meridians), render it very probable that the present position of the south magnetic pole is in the interior of the great Antarctic land called South Victoria, west of the Albert Mountains, of which the active volcano Mount Erebus, rising to the height of more than 12000 feet, forms a part.

The situation, and the alterations in the form of the magnetic equator, or line on which the dip is 0, have been already spoken of by me in the "Description of Nature" in Vol. i. (S. 190—192 and 431; Engl. p. 172—174, and 411). The earliest determination of the African node (the intersection of the geographical and magnetical equators) was by Sabine, at the commencement of his Pendulum Expedition in 1822([126]): at a later period, 1840, the same savant, by combining the observations of Duperrey, Allen, Dunlop, and Sulivan, formed a map of the magnetic equator([127]), from the west coast of Africa, (4° N. lat., 9° 32′ E. long.) through the Atlantic Ocean and Brazil (16° S. lat. between Porto Seguro and Rio Grande), to the point where I had found north dip change to south, on the Cordilleras, not far from the Pacific. The African node, or point of intersection of the two equators, was, in 1837, in 3° 02′ E. long.; in 1825 it had been in 6·57′ E. long. The secular movement of the node, in receding to the westward from the lofty basaltic island of St. Thomas, had therefore been at the annual rate of rather less than half a degree, thus causing the line of no dip to impinge on the African coast at a progressively more northern point; whilst at the same time it descended more to the south on the Brazilian coast. The convex summit of the magnetic equator continues to be directed towards the south, its maximum

distance from the geographical equator in the Atlantic Ocean being 16°. In the interior of South America, in the Terra incognita of Matto Grosso, between the great rivers Xingu, Madera, and Ucayale, there is an entire absence of observations until the chain of the Andes is reached, where, 68 miles east of the Pacific, between Montan, Micuipampa, and Caxamarca, I determined astronomically the place of the magnetic equator, (7° 2′ S. lat., 78° 46′ W. long.), which is there in course of ascending to the north-west(128)

The most complete investigation which we possess towards a knowledge of the whole course of the magnetic equator, is that made by my friend Duperrey, for the years 1823—1825. In the course of his voyage of circumnavigation, he crossed the magnetic equator six times, and has been enabled to lay it down from his own observations for 220 degrees of longitude.(129) The two nodes are situated, according to Duperrey's map of the magnetic equator, one in about 6° E. long. in the Atlantic Ocean, the other in 177½° E. long., in the Pacific, between the meridians of the Viti and Gilbert Islands. After quitting the west coast of the South American continent, probably between Punta de la Aguja and Payta, the magnetic equator continues, in its prolongation westward, to approach the geographical equator, until, in the meridian of the Mendaña group of islands, the two equators are only two degrees apart.(130) Ten degrees further to the west, in the meridian of the western part of the Paumotu Islands, or Low Archipelago, in 154° E. long., Captain Wilkes, in 1840, found a similar distance of fully two degrees of latitude between the geographic and magnetic equators.(131) The intersection or node in the Pacific is not 180° from the node in the Atlantic, being situated, not

in 174° W. long., but in the meridian of the Viti group, in about 177½° E. or 182½° W. long. Therefore, in proceeding to the west from the coast of Africa, we find the distance between the two nodes 8½° greater than the earth's semi-circumference,—a proof that the curve in question is not a great circle.

According to the excellent and widely-extended determinations of Captain Elliot (1846—1849), which between the meridians of Batavia and Ceylon are remarkably accordant with those of Jules de Blosseville (see p. 67 of the present volume), the line of no inclination passes across the north of Borneo, and running in an almost exactly east and west direction, touches the north point of Ceylon (9° 45′ N. lat.) The curve of least total force is in this part of the world almost parallel with that of the magnetic equator.(132) The latter enters the east coast of Africa south of Cape Gardafui: this important point has been determined with great exactness by Rochet d'Hericourt in his second Abyssinian expedition (1842—1845), and by the able discussion of that traveller's magnetic observations.(133) It is situated south of Gaubade, between Angolola and Angobar (the principal town of the kingdom of Shoa), in 10° 7′ N. lat. and 41° 13′ E. long. The course of the magnetic equator through the interior of Africa, from Angobar to the Bight of Biafra, is as entirely unexamined as is the portion of the same line which passes through that part of the interior of South America which is east of the chain of the Andes and south of the geographical equator. These two continental spaces are of about equal extent in an east and west direction, and taken together occupy 80 degrees of longitude, or nearly a quarter of the earth's circumference, in which there

is thus as yet an entire absence of magnetic determinations. My own observations of inclination and force through the whole *interior* of South America (from Cumana to Rio Negro, as well as from Cartagena de Indias to Quito) were confined to the tropical zone north of the geographical equator; those in the southern hemisphere, from Quito to Lima, only extended over the narrow district adjacent to the western coast.

The movement of translation of the African node to the westward from 1825 to 1837, noticed in a preceding page, is confirmed, on the east coast of Africa, by a comparison of the inclination observed by Panton, in 1776, with Rochet d'Héricourt's observations. The last-mentioned traveller found the line of no dip much nearer the Straits of Bab-el-Mandeb, *i. e.* 1° south of the island of Socotora in 8° 40′ N. lat. Thus there would appear to have been in 49 years only an alteration of 1° 27′ in latitude: the alteration in longitude in the same interval of time, by the movement of the node as estimated by Arago and Duperrey, would amount to 10° to the westward. The direction of the movement due to secular change on the eastern side of Africa has therefore been quite the same as on the western, but the quantity or amount of the movement still requires to be determined by more exact results.

The *periodicity* of the variations in the magnetic inclination, in reference to hours and seasons, the existence of which has been already remarked, has only been established definitively, and in its entire character, within the last twelve years, or since the formation of the British magnetic stations in the two hemispheres. Arago, to whom so much is due

in reference to magnetism, had indeed recognised in the autumn of 1827 that "the inclination is greater at 9 A.M. than at 6 P.M.; while the intensity of the magnetic force, as measured by the vibrations of a horizontal needle, attains its minimum at the former, and its maximum at the latter, of these two epochs."(134) The whole diurnal march of the inclination has now been solidly established by means of many thousand regularly continued hourly observations at the British magnetic observatories since 1840, and by their laborious discussion. This is the place for bringing together the obtained facts as the foundations of a general theory of terrestrial magnetism. Before doing so, it is desirable to remark that, in considering the periodic fluctuations of the three elements of terrestrial magnetism in their entire character, we ought, with Sabine, to distinguish in the "turning hours," or hours of maxima or minima, between two greater, and therefore important, extremes; and other intervening minor (though for the most part not less regular) fluctuations. The recurring movements of the inclination and declination needles present to us, then, as do the variations of the intensity of the total force, principal and secondary maxima and minima; in the most usual cases both principal and secondary, forming a double progression with four turning hours, but less commonly a single maximum and minimum only, forming a simple progression with but two turning hours. The march of the total force in Van Diemen Island, for example, is of the latter description, while the inclination at the same station follows a double progression; and at Toronto, in Canada, a place whose position in the northern hemisphere corresponds almost exactly to that of Hobarton in the southern hemisphere, the diurnal march of

the total force is a double progression, whilst that of the inclination is a double progression only from October to March, and a single progression from April to September.(135) At the Cape of Good Hope the inclination has only a single maximum and single minimum, whilst the total force has a double progression, the principal minimum occurring at the same hour as the minimum of inclination.

We must also distinguish between results obtained by a series of observations with a dipping-needle at certain hours of the forenoon compared with a similar series at certain hours in the afternoon (which can at most only give the difference in the amount of the inclination at those two periods of the twenty-four hours), and results obtained by hourly observations of the horizontal and vertical force magnetometers, which give the horary variations of the inclination and total force for every hour. Amongst the horary variations of the inclination obtained by either of these methods may be cited the following:—

I. *In the Northern Hemisphere.*

Greenwich. From observations with a dipping-needle three hours before and three hours after noon, the north dip was found to be greater at 9 A.M. than at 3 P.M. The difference in 1847 was 0′·7. In four years out of five, the dip was higher at 9 A.M. than at 3 P.M., but in one year (1845) the reverse appeared, the dip being greater by 1′·3 at 3 P.M. than at 9 A.M.

Paris. From observations with a dipping-needle at 9 A.M. and 6 P.M., the mean north dip appeared to be greatest at 9 A.M.

Petersburg. From observations with a dipping-needle at 8 A.M. and 10 P.M., the mean north dip appeared to be greatest at 8 A.M.

Toronto, in Canada. From hourly observations during 5½ years with horizontal and vertical force magnetometers, a principal maximum is found in all months of the year about the hour of 4 P.M., occurring, however, somewhat earlier from April to September than from October to March; and a principal minimum about 10 A.M. or 11 A.M., occurring also earlier from April to September than from October to March. The progression from the maximum at 10 or 11 A.M. to the minimum at 4 P.M. is continuous and rapid. From April to September the inclination increases, with occasional very slight interruptions, from the minimum at 4 P.M. to the maximum at 10 A.M. At this season, therefore, the horary variation scarcely differs from a single progression, the decrease taking place in the six hours from 10 A.M. to 4 P.M., and the increase, more slowly, in the remaining eighteen hours. In the opposite season, *i. e.* from October to March, a secondary maximum shows itself at from midnight to 2 A.M., and a secondary minimum at about 6 A.M. (Sabine, Toronto, Vol. ii. p. lxx.) The north dip is greater in the six months when the Sun is in the southern signs (75° 17′·84) than in the six months when the Sun is in the northern signs (75° 16′·57). The intensity of the total force is also greater by about two-thousandth parts of its whole amount in December and January, when the Earth is nearest to the Sun, than in June and July, when the Earth is most distant from the Sun. (Toronto Obs. Vol. ii. pp. lxxxvii. and xcii. and xciii.)

II. *In the Southern Hemisphere.*

Hobarton, Van Diemen Island. From hourly observations during six years with horizontal and vertical force magnetometers, the principal maximum (of south dip) occurs at 11½ A.M.; the principal minimum at 6 A.M.; a secondary maximum at 10 P.M.; and a secondary minimum at 5 P.M. (Sabine, Hobarton, Vol. i. p. lxvii.) The south dip is greater in the six months when the Sun is in the southern signs ($-70° 36'·60$) than when in the northern signs ($-70° 35'·42$). The intensity of the total force is also greater at Hobarton from December to February than from June to August. (Hobarton Obs. Vol. ii. p. xlvi.)

Cape of Good Hope. From hourly observations during 4½ years with horizontal and vertical force magnetometers, a single progression is found. Maximum at 8 h. 34 m. A.M.; minimum at 0° ′·34 P.M.; with a very small intervening fluctuation between 7 A.M. and 9 A.M.

In comparing the two stations of Toronto and Hobarton, situated in corresponding latitudes on either side of the equator, we notice remarkable correspondencies in respect to the turning hours; thus

10 to 11½ A.M. is the epoch of principal minimum at Toronto, and of principal maximum at Hobarton.

4 P.M. is the epoch of principal maximum at Toronto, and 5 P.M. of secondary minimum at Hobarton.

6 A.M. is the epoch of principal minimum at Hobarton, and of secondary minimum at Toronto; and from

10 P.M. to 2 A.M. a secondary maximum occurs at both stations.

The four turning hours of the inclination at Toronto are almost exactly reproduced at Hobarton, only the signification is altered. This complex action is very deserving of attention; as is also the comparison of the two stations in respect to the sequence of the turning hours of the variations of the inclination and of the total force.([136])

The periods of the inclination at the Cape of Good Hope do not agree either with Hobarton, which is in the same hemisphere, or with any of the northern stations which have been referred to. The minimum of inclination even takes place at an hour when the inclination at Hobarton has almost reached its maximum.

The determination of the secular change of the inclination requres observations of equal and satisfactory accuracy, repeated so as to include long intervals of time. We do not, for example, find that we can go back to Cook's voyages with the desired degree of certainty; for although in his third voyage the poles of the dipping-needle were always reversed, yet differences from forty to fifty-four minutes occur between that great navigator's observations in the Pacific and those of Bayley,—attributable probably to the then very imperfect construction of the needles, and especially to their want of free movement. For London, we are reluctant to go back beyond Sabine's observations in August 1821, which, compared with the excellent determination by James Ross, Sabine, Johnson, and Fox, in 1838, gave for that interval an annual rate of decrease of 2′·73; in near accordance with which, Lloyd, with equally

exact instruments, but in a shorter interval of time, found for Dublin 2′·38 annual decrease.(137) In Paris the inclination is also diminishing, and more rapidly than in London. The very ingenious methods of determining the dip devised by Coulomb were not practically successful in the hands of their inventor, for he was led by them to erroneous results. The first observation with a good instrument of Lenoir's was made in 1798 at the Observatory of Paris, when, conjointly with Chevalier Borda, I found by several repetitions 69° 51′·0; in 1810, I found, conjointly with Arago, 68° 50′·2; and in 1826, with Mathieu, 67° 56′·7. In 1841 Arago found 67° 9′·0; and in 1851 Laugier and Mauvais found 66° 35′: all these determinations were made by the same method, and with similar instruments. The entire period, exceeding half a century, (1798 to 1851) gives a mean annual decrease of inclination at Paris of 3′·69, being for the several intervals:

from	1798 — 1810	at the rate of	5′·08
	1810 — 1826	,,	3′·37
	1826 — 1841	,,	3′·13
	1841 — 1851	,,	3′·40

The rate of decrease underwent a remarkable retardation between the first and second interval, but the change was a gradual one, for a very careful observation of Gay-Lussac's, made in 1806 on his return from Berlin, where he had accompanied me after our return from our Italian journey, gave the inclination 69° 12′, corresponding to a rate of decrease of 4·87. The nearer the node of the magnetic equator, in its secular movement from east to west, ap-

proaches the meridian of Paris, the more the rate of decrease appears to slacken, the retardation being in the course of half a century from 5′·08 to 3′·40. In a memoir which I presented to the Berlin Academy in April 1829, a short time before my Siberian expedition,(138) I collected and compared the observations made by me,—I think I may venture to say, always with equal care. Sabine measured the inclination and the force at the Havannah fully twenty-five years after my observations there, thus giving for that tropical station the variation of two important magnetic elements for a considerable interval. Hansteen (1831) has examined the annual variation of the inclination in either hemisphere in a very meritorious and more comprehensive work (139) than mine.

While the observations of Sir Edward Belcher in 1838, compared with mine in 1803, indicate considerable changes of inclination along the west coast of America, between Lima, Guayaquil, and Acapulco (vide page 77) (the longer the interval, the greater the value of the results), the secular change in other parts of the Pacific appears to have been remarkably small. At Otaheite, Bayley found, in 1773, 29° 43′; Fitz Roy, in 1835, 30° 14′; Belcher, in 1840, 30° 17′, so that in sixty-seven years the mean annual increase would hardly have been 0′·51(140) In Northern Asia, also, a very careful observer, Mr. Sawelieff, twenty-two years after my visit to those regions, found on a journey which he made from Kasan to the shores of the Caspian, that very unequal changes had taken place in the inclination on the north and south sides of the parallel of 50° of geographical latitude.(141)

	Humboldt. 1829.	Sawelieff. 1851.
Kasan	68° 26′·7	68° 30′·8
Saratoff . . .	64° 40′·9	64° 48′·7
Sarepta . . .	62° 15′·9	62° 39′·6
Astrachan . .	59° 58′·3	60° 27′·9

For the Cape of Good Hope we possess a very long, and if we do not go further back than from Sir James Ross and Du Petit Thouars in 1840, to Vancouver in 1791, a very satisfactory comparison of observations of inclination, comprising an interval of almost fifty years.(142)

The question whether the height of the station has any unequivocally discernible influence on the magnetic inclination and force,(143) was the subject of careful examination by me in my journeys in the Andes, the Ural, and the Altai Mountains. I have already remarked, in the section on the Force, how few unfortunately are the localities which are suited to throw any certain light upon this inquiry, as the points compared ought to be so near to each other as to avoid all suspicion that the magnetic differences may be due, not to the difference of elevation, but to the inflections of the isodynamic and isoclinal curves, or to diversity in the character of the rocks. I will confine myself to the four principal results of the inclination in respect to which I thought at the time, and on the spot, that they indicate, with greater certainty than the force observations, an influence of elevation in diminishing the inclination of the needle.

On the Silla de Caracas, which rises almost perpendicularly 8100 French feet above the sea-coast of La Guayra,

south of the coast and north of the town of Caracas, incl. 41°·90: La Guayra, elev. 10 feet; incl. 42°·20: town of Caracas, elev. 2484 French feet; incl. 42°·95. (Humboldt, Voy. aux Régions équinox. T. i. p. 612.)

Santa Fé de Bogota: Elev. 8196 French feet; incl. 27°·15: Chapel de Nuestra Señora de Guadalupe, on a precipice above the town, elev. 10128 French feet; incl. 26°·80.

Popayan: Elev. 5466 French feet; incl. 23°·25: mountain village of Purace, on the declivity of the volcano, elev. 8136 French feet; incl. 21°·80: summit of the volcano of Purace, elev. 13650 French feet; incl. 20°·30.

Quito: Elev. 8952 French feet; incl. 14°·85: San Antonio de Lulumbamba, where the geographical equator passes through the hot valley; elev. of the bottom of the valley, 7650 French feet; incl. 16°·02. All the above inclinations are given, as observed, in centesimal degrees, as their comparative value is the only point under consideration.

On account of the too great horizontal distances between the stations, and the influence of adjacent rocks, I do not lay any stress on my European observations: as, for example, at the Hospice on St. Gothard (6650 French feet), incl. 66° 12′, compared to Airolo (3502 French feet), incl. 66° 54′, and Altorf, incl. 66° 55′; or (which seem to tell the other way) Lans le Bourg, incl. 66° 9′; Hospice on Mount Cenis (6358 French feet), incl. 66° 22′; and Turin (707 French feet), incl. 66° 3′; or at Naples, Portici, and the crater of Vesuvius; or in Bohemia, the summit of the great Milischauer (a Phonolite!), incl. 67°53′; Töplitz, incl. 67°19′·5; and Prague, incl. 66° 47′·6.(144) In 1844 Bravais, in company with Martins and Lepileur, made a series of

excellent comparative horizontal force observations (published in great detail) at 35 stations, including the summits of Mont Blanc (14809 French feet), the Great St. Bernard (7848 French feet), and the Faulhorn (8175 French feet); contemporaneously with which were observations of the inclination on the Grand Plateau of Mon Blanc (12097 French feet), and at Chamounix (3201 French feet). If the comparison of these results would indicate a diminution of inclination with increased elevation, observations on the Faulhorn and at Brienz (1754 French feet) on the other hand, would give the contrary indication. Thus no satisfactory solution of the problem was obtained by either class of experiment. (Bravais sur l'intensité du Magnétisme terrestre en France, en Suisse et en Savoie, in the Annales de Chimie et de Physique, 3ème Série, T. xviii. 1846, p. 225.) In a manuscript of Borda's on the subject of his expedition to the Canaries in 1776, (preserved in the Dépôt de la Marine at Paris, and for the communication of which I am indebted to Admiral Rosily), I have found the proof that Borda made the first attempt to examine the influence of height on this magnetic element. He found the inclination on the summit of the Peak of Teneriffe 1° 15′ greater than in the port of Santa Cruz,—a difference, no doubt, in great part at least, the consequence of the local attraction of the lavas, similar to that which I have myself often observed on American volcanoes and on Vesuvius. (Humboldt, Voy. aux Rég. équinox. T. i. pp. 116, 277, and 288.)

With the view of trying the analogous question of the influence of depth below the earth's surface, being at Freiberg in July 1828, I made observations of the inclination

with the greatest care of which I am capable, and always reversing the poles of the needles, in a mine in which the strictest examination could detect no influence of the rock (gneiss) upon a magnetic needle. The depth below the surface was 802 French feet. The difference of the subterranean inclination from that observed at a point immediately above it is, indeed, only 2′·06, but from the precautions taken in the whole proceeding, the results of the several needles which are stated in a note,([145]) induce me to believe that the inclination is really greater below than at the surface. It is very desirable to repeat similar trials with care, in favourable localities and where it can be ascertained that the strata are free from all local influence, in mines of greater depth,—as that of Valenciana, near Guanaxuato in Mexico, 1582 French feet,—in English coal mines more than 1800 feet deep,—or in the now ruined Eselschacht,([146]) at Kuttenberg in Bohemia, 3545 French feet in vertical depth!

After a violent earthquake at Cumana, on the 4th of November, 1799, I found the inclination was diminished 90 centesimal minutes, or nearly a whole degree. The circumstances under which I obtained this result, of which I have given elsewhere an exact relation,([147]) offer no satisfactory reason for supposing an error. A short time after landing at Cumana, I had found the inclination 43°·53 (Centesimal). The accident of having seen, a few days before the earthquake, in an otherwise estimable Spanish work, Mendoza's Tratado de Navegacion, T. ii. p. 72, the erroneous opinion, that the diurnal and annual variations of the inclination are greater than those of the

declination, had occasioned me to institute, in the harbour of Cumana, a series of careful observations. From the 1st to the 2nd of November the inclination continued with great steadiness to show a mean amount of 43°·65. The instrument remained untouched and properly levelled, in the same place. On the 7th of November, three days after the strong earthquake shocks, the instrument, after being levelled afresh, gave 42°·75. The intensity of the magnetic force, measured by vertical oscillations, was unaltered. I hoped that the inclination would return, perhaps gradually, to its former value; but it remained the same. On returning to Cumana in September 1800, after travelling by river and land journeys on the Orinoco and Rio Negro upwards of two thousand geographical miles, the same dipping-needle of Borda's, which had accompanied me everywhere, gave the inclination 42°·80,—very nearly the same as in the last observation before it left Cumana. As mechanical agitations and electric shocks, by altering the molecular condition in soft iron, elicit poles, so we may conceive it possible that there may be a connection between the direction of magnetic currents and that of earthquake shocks; but although my attention was strongly directed towards a phænomenon of the objective reality of which I had in 1799 no reason to doubt, yet, in the numerous earthquake shocks which I experienced during the three years subsequently passed in South America, I never again met with a sudden alteration of the magnetic inclination which I could ascribe to such a cause, various as were the directions in which the undulatory movement of the terrestrial strata was propagated. A very accurate and experienced observer,

Erman, also found, after an earthquake on Lake Baikal on the 8th of March, 1828, no disturbance either in the amount of the declination or in its periodic variation.(148)

Declination.

I have already touched, in the earlier part of the present volume, on the historical facts of the earliest recognition of phænomena relating to the third element of terrestrial magnetism,—the declination. In the 12th century of our era, the Chinese were not only acquainted with the fact of the deviation of a horizontal magnetic needle, suspended by a cotton thread, from the geographical meridian, but they also knew how to determine the amount of this deviation. When afterwards, by the intercourse of the Chinese with the Malays and Indians, and of these with the Arabs and the Moorish pilots and navigators, the use of the mariners' compass became common among the Genoese, Majorcans, and Catalans in the Mediterranean, on the west coast of Africa, and in the Northern Seas, indications of the variation (or declination) came to be introduced in nautical charts of different parts of the ocean, even as early as 1436.(149) The geographical position of a line of no variation, on which the needle pointed to the true north or pole of the Earth's rotation, was determined by Columbus on the 13th of September, 1492: it even did not escape him that the knowledge of the magnetic declination might serve to determine the geographical longitude. I have shown elsewhere, from his ship's journal, that on his second voyage (April 1496), when uncertain about his ship's reckoning, he sought to aid himself by observations of

declination.(150) The horary variations or changes of declination were recognised as facts by Hellibrand and Tachard, at Louvo, in Siam; they were first observed, circumstantially and almost satisfactorily, by Graham in 1722. Celsius was the first who arranged concerted simultaneous measurements of these variations by different observers at two distant points.(151)

Passing now to the phænomena presented by the declination of the magnetic needle, we will consider them, first, in reference to their variations according to the hours of the day or night, the seasons of the year, and their mean state in different years; next in regard to the influence exercised on those variations by the extraordinary, and yet periodic, disturbances, and by the position of the places of observation to the north or south of the magnetic equator; and lastly, we will consider them according to the linear relations of places on the earth's surface having equal, or (it may be) no, declination. These linear relations are indeed that part of the acquired knowledge which is the most important in its direct and practical application to navigation; but all the general magnetic phænomena (among which the extraordinary disturbances, or magnetic storms, acting often simultaneously at such great distances, are among the most mysterious), are so intimately connected together, that, with a view to the gradual completion of the mathematical theory of terrestrial magnetism, we should neglect none of them.

In the middle latitudes of the northern magnetic hemisphere (dividing the earth at the magnetic equator), the north end of the needle, *i. e.* the end which points in those latitudes towards the north, points more to the east at

$8\frac{1}{4}$ A.M. ($20\frac{1}{4}$ astronomical reckoning) than at any other hour, making then the nearest approach to the true or geographical north at all places where the declination is westerly. From that hour this end of the needle moves gradually westward until $1\frac{3}{4}$ P.M., when it reaches its most westerly elongation. This movement to the westward is general; it takes place in the same direction at all places in the middle latitudes of the northern hemisphere, whether they have west declination, as the whole of Europe, Pekin, Nertschinsk, and Toronto in Canada; or east declination, as Kasan, Sitka (in Russian America), Washington, Marmato in New Granada, and Payta on the coast of Peru.([152]) From the above-mentioned most westerly pointing at $1\frac{3}{4}$ h., the needle returns towards the east during the afternoon and a portion of the night until 12 h. or 13 h.,—often making, however, a small pause at about 6 h. In the night there is again a small movement to the westward, after which the easterly march is resumed until the most easterly pointing of the needle is attained, which, as already stated, is at $20\frac{1}{4}$ h. astr., or $8\frac{1}{4}$ A.M. This nocturnal period, which was formerly quite overlooked,—a gradual and uninterrupted progression to the east from $1\frac{3}{4}$ P.M. until the morning hour of 8 having been the general belief,—strongly engaged my attention at Rome, when I was occupied there with Gay-Lussac in examining the horary variations of the declination with a Prony's magnetic telescope. The needle being generally more unquiet while the sun is below the horizon, this small nocturnal movement to the west presents itself on that account both less frequently and less distinctly to the recognition of the observer. When it does show itself distinctly, I have noticed it to be unaccompanied by any

agitation of the needle. Quite differently from what is the case during what I have termed magnetic storms, the needle in this small westerly night excursion travels quietly from one scale division to another, just as it does in the well-assured and strongly characterised day movement between $20\frac{1}{4}$ h. and $1\frac{3}{4}$ h. It is very noticeable, and well deserving of attention, that when the needle exchanges its continuous westerly movement for an easterly one, or *vice-versâ,* it does not remain for a time without altering its direction, but (especially in the case of the $20\frac{1}{4}$ h. to $1\frac{3}{4}$ h. period) turns suddenly back. The small westerly movement usually takes place between midnight and early morning; but it has been noticed in Berlin, in the Freiberg subterranean observations, at Greenwich, at Makerstoun in Scotland, at Washington, and at Toronto, as early as between 10 and 11, or 11 and 12 hours.

The four movements of the declination-needle recognised by me in 1805([153]) are presented as the result of many thousand two-hourly observations made at Greenwich in the years 1845, 1846, and 1847, four turning hours being there assigned as follows([154]):—Principal minimum of westerly declination at 20 h.; principal maximum at 2 h.; secondary minimum at 12 h. or 14 h.; secondary maximum at 14 h. or 16 h. (the declination being westerly). I must here content myself with giving the mean hours, and calling attention to the circumstance that in our northern zone the hour of the principal morning minimum (20 h.) is not at all altered by the earlier or later time of sunrise. During two solstitial and three equinoctial periods, for each of which Oltmanns and myself followed the march of the horary variation of the declination for five or six days and as

many nights, I always found the easternmost turning-point of the needle, in the summer as in the winter months, between $19\frac{3}{4}$ h. and $20\frac{1}{4}$ h.; being very slightly,(155) if it might be said to be at all, accelerated, by the earlier time of sunrise in the summer.

In the high northern latitudes, near or within the arctic circle, the regularity of the horary variation has been as yet but imperfectly made out, although we possess a number of very exact observations. In Iceland, Lottin, in the French scientific expedition of the 'Lilloise' in 1836, was almost afraid (considering the local influence of rocks, and the frequency of Auroras) to derive any determinate results in respect to the turning hours, either from his own extensive and laborious observations, or from the earlier ones (1786) of the meritorious Löwenörn. On the whole, at Reikiavik, in Iceland, lat. 64° 8′, as well as at Godthaab on the Greenland coast according to the missionary Genge's observations, the minimum of westerly declination appears to fall almost as in the middle latitudes, at 21 h. or 22 h., but the maximum not until 9 h. or 10 h. in the evening.(156) Further to the north, at Hammerfest, in Finmarken, in lat. 70° 40′, Sabine found the march of the declination tolerably regular,(157) and similar to that in the south of Norway and in Germany; westerly minimum at 21 h., westerly maximum at $1\frac{1}{2}$ h.; but he found it very different in Spitzbergen in lat. 79° 50, where the corresponding turning hours were 18 h. and $7\frac{1}{2}$ h. For the Arctic Islands north of America, we have at Port Bowen, on the eastern side of Prince Regent's Inlet (lat. 73° 14′), from Captain Parry's third voyage (1825), a fine series of five months' consecutive observations by Lieuts. Foster and James Ross:

but although the needle passed twice in the twenty-four hours through the direction regarded as the mean magnetic meridian of the place,—and although for fully two months (April and May) no Aurora was seen,—yet the times of the principal elongations varied from four to six hours; nay, more, the mean epochs of the maxima and minima of west declination from January to May were only one hour apart! The amount of variation was so great that on some days the declination varied from $1\frac{1}{2}°$ to 6° and 7°; (within the tropics the differences hardly reach as many minutes.(158) Not only within the polar circle, but also within the tropics, *e. g.* at Bombay (lat. 18° 56′), there is great complexity in the periods of the horary variation of the declination. They there fall under two principal classes, being very different from April to October and from October to December; and these again subdivide into two minor periods, which are far from being well defined.(159)

European nations knew from their own experience nothing respecting the direction of the magnetic needle in the *southern* hemisphere until the second half of the 15th century, when through the adventurous voyages of Diego Cam and Martin Behaim, Bartholomew Diaz and Vasco de Gama, some slight notice on the subject reached Europe. The importance which, as we learn from their early writers, was attached to the *south* end of the magnetic needle by the Chinese (who, as well as the inhabitants of Corea and of the islands of Japan, guided themselves at sea as well as on land by the compass as early as the 3rd century of our era), was no doubt occasioned principally by the circumstance that their navigation was mainly directed to the south and south-west. On these southern voyages it had not escaped

them that the south end of the needle by which they steered did not point precisely due south. We have even the statement belonging to the 12th century, from one of their determinations, of the amount of the "variation to the south-east."(160) The extension of the use of the mariners' compass was much favoured by the very ancient connection of China and India with Java,(161) and in a still greater degree by the visits of people of Malay race to Madagascar, and their settlements there.

Although, judging from the present very northerly position of the magnetic equator, it is probable that when the missionary Guy Tachard remarked the existence of horary variations of the declination in 1682 at the town of Louvo in Siam, that place was nearly out of the northern magnetic hemisphere,—yet it must be acknowledged that accurate horary declination-observations were not made in the southern magnetic hemisphere until a full century later. In 1794 and 1795, John Macdonald followed the march of the needle both at Fort Marlborough on the south-west coast of Sumatra, and at St. Helena.(162) The results then obtained called the attention of physicists to the great decrease in the amount of the diurnal variation of the declination in the lower latitudes; the differences between the extremes at these stations amounting only to 3 or 4 minutes. A more comprehensive and deeper knowledge of the phænomenon was gained by the scientific expeditions of Freycinet and Duperrey; but it is the establishment of magnetic observatories at three important points of the southern magnetic hemisphere,—at Hobarton in Van Diemen Island, at St. Helena, and at the Cape of Good Hope (at which places hourly observations on the variation of the three elements

of terrestrial magnetism have been made on a uniform system for several years),—which has first supplied general and complete data. The march of the needle in the middle latitudes of the southern magnetic hemisphere is quite the opposite of its march in the northern hemisphere; for as in the south, the end of the needle which points towards the south moves from morning to noon from the east towards the west, it follows that the north-pointing end of the same needle is moving at the same time from the west towards the east, contrary to what we have described above as its march during those hours in our own hemisphere.

Sabine, to whom we are indebted for the sagacious discussion of all these variations, has so combined five years of hourly observation at Hobarton (42° 53′ S. lat., 9° 57 E. decl.) and at Toronto (43° 39′ N. lat., 1° 33′ W. decl.), that the periods from October to February and from April to August are distinguished from each other, the omitted intervening months of March and September presenting, as it were, transitional phænomena. At Hobarton the north end of the needle has daily two easterly and two westerly maxima of elongation.(163) In the portion of the year from October to February, the movement takes place towards the east from 20h. or 21h. to 2h.; there is then a small movement towards the west from 2h. to 11h., from 11h. to 15h. again to the east, and from 15h. to 20h. the needle returns to the west. In the portion of the year from April to August the eastern turning hours are retarded to 3h. and 16h., and the western turning hours are made earlier, being at 22h. and 11h. In the northern hemisphere, the westward movement of the needle from 20h. to 1h. is greater when the Sun is in the northern than when he is in the southern signs:

in the southern hemisphere, where between those two hours the direction of the movement of the needle is an opposite one, its amount is greater when the Sun is in the southern than when he is in the northern signs.

The question which I touched upon seven years ago in Vol. i. of this work (164),—*i. e.* whether there be a region of the earth, perhaps between the geographical and magnetic equators, in which, as a transitional region between the parts of the earth in which the declination-needle moves at the same hours in opposite directions, *no* horary variation might be found?—appears from subsequent experience, and especially from Sabine's perspicuous discussion of the observations at Singapore (1° 17′ N. lat.), at St. Helena (15° 56′ S. lat.), and at the Cape of Good Hope (33° 56′ S. lat.), to require to be answered in the negative. Hitherto no place has been found at which the needle is without diurnal movement (horary variation); and through the establishment of the magnetic stations we have been made aware of the important and very unexpected fact, that there are in the southern magnetic hemisphere places at which the diurnal variation of the magnetic needle appears to participate in the phænomena, or to conform to the type, of either hemisphere *alternately*. The Island of St. Helena is situated very near to the line of weakest intensity of the earth's magnetic force, in a part of the earth where that line recedes widely both from the geographical equator and from the line of no inclination. At St. Helena, the march of the north end of the needle in the hours of the forenoon, in the months from May to September, is the opposite of the march followed by the same end of the needle in the corresponding hours from October to February. According to five years

of hourly observation in the first-named portion of the year, viz. from May to September, while the Sun is in the northern signs, being the winter of the southern hemisphere, the declination-needle points at 19h. furthest to the *east* of its mean direction, and from that hour moves as it does in the middle latitudes of Europe and North America towards the *west* until 22h., and remains nearly stationary until 2h. On the other hand, in the opposite portion of the year, from October to February, the summer of the southern hemisphere, when the Sun is in the southern signs, and the Earth is nearest to the Sun, the needle points at 20h. most to the *west*, and its movement from thence to noon is to the *east*, precisely in accordance with the type of Hobarton (in 42° 53′ S. lat.) and other places in the middle latitudes of the southern hemisphere. At the time of the equinoxes, or soon after, in March and April, and in the latter portion of September, the march of the needle fluctuates on different days, forming periods of transition from the type of the southern to that of the northern, and from that of the northern to that of the southern hemisphere.([165])

Singapore is situated a little to the north of the geographical equator, between it and the magnetic equator, which in this part of the earth is almost coincident, according to Elliot, with the line of least force. According to the observations made every two hours at Singapore for the years 1841 and 1842, Sabine finds there the same opposite types in the diurnal march of the needle from May to August, and from November to February, as at St. Helena; and so also at the Cape of Good Hope, although the latter station is 34° from the geographical equator, and doubtless still further from the magnetical one (the magnetic dip at the Cape

being 53° S.); and the Sun of course never passes through its zenith.(166) We already possess several years of published hourly observations, from which it appears that at this station, almost precisely as at St. Helena, the needle from May to September moves westward from its extreme eastern position at $19\frac{1}{2}$h. until $23\frac{1}{2}$h.; and from October to March the movement is, on the contrary, eastward from $20\frac{1}{2}$h. to $1\frac{1}{2}$h. or 2h. The discovery of this phænomenon, of which the existence is so well demonstrated, while at the same time its causal connection is still veiled in such profound obscurity, shows forcibly the importance of the system of hourly observations continued uninterruptedly for several years. Disturbances which, as we shall presently see, deflect the needle persistently, at one time to the west and at another to the east, would prevent any well-assured inferences being derived from isolated observations by travellers.

The extension of navigation, and the use of the compass in geodesical surveys, led very early to the remark of occasional extraordinary disturbances in the direction, accompanied by fluctuating, starting, or tremulous movements, of the needles employed. This used to be ascribed to a certain condition of the particular needle: it was very characteristically termed, in the French nautical language, "l'affolement de l'aiguille," and it was recommended that "une aiguille affolée" should be magnetised afresh, and more powerfully. Halley was the first who stated the Aurora to be a magnetic phænomenon(167),—on the occasion of his being asked by the Royal Society of London, to explain the "great meteor" of the 6th of March, 1716, seen over the whole of England, and which, in his reply, he considered to be "analogous to that to which Gassendi in 1621 had first given the name of Aurora

borealis." We know from his own statement that prior to 1716 Halley had never seen either a northern or a southern Aurora; although, in his voyages for determining the declination lines, he had advanced to the 52nd degree of south latitude:—and southern Auroras are assuredly sometimes seen within the tropics, as in Peru. It would appear, therefore, that Halley had never himself observed the remarkable disturbances and fluctuations of the needle in conjunction with seen (or unseen) northern or southern Auroras. Olav Hiorter and Celsius, at Upsala, were the first who, in 1741 (before Halley's death), confirmed by a long series of observations the connection between a visible Aurora and disturbance from the normal march of the magnetic needle, which was only conjectured by Halley. This meritorious undertaking gave occasion to the first *concerted simultaneous* observations in conjunction with Graham in London: extraordinary disturbances of the declination accompanying displays of Aurora were examined specially by Wargentin, Canton, and Wilke.

Observations which I had the opportunity of making together with Gay-Lussac in 1805, at Rome, on the Monte Pincio, and more particularly a more extensive series which I was thereby led to undertake in conjunction with Oltmanns, at the equinoxes and solstices of 1806 and 1807, in a large and well-detached garden at Berlin (employing a magnetic telescope of Prony's, and a distant point of reference well illuminated by a lamp),—made me early aware that that part of the telluric magnetic activity described under the general name of "extraordinary disturbances," which acts so powerfully at particular periods and in no merely local manner, deserved, and from its complicated character required, a persistent

system of examination. The arrangement of the mark and of the cross of wires in the telescope, which was suspended by either a silken or metallic thread, and enclosed in a large glass case, permitted readings to be taken to eight seconds of arc. In this method of observation, the room in which the magnetic telescope was placed might be left dark, thus avoiding the disturbing effects of currents of air, which may be occasioned by the means required for illuminating the scale of otherwise excellent declinometers furnished with microscopes. Entertaining the opinion which I then expressed, that "a continued uninterrupted hourly or half-hourly process of observation (observatio perpetua) for several days and nights was to be preferred to the detached observations of many months," we observed consecutively for five, seven, or eleven days, and as many nights,([168]) at the periods of the solstices and equinoxes, epochs of which all the most recent investigations have confirmed the great importance. We soon recognised, that in order to study the proper physical character of these anomalous disturbances, it was not sufficient to determine the measure or quantity of the deviation from the change in the declination, but that there should be added thereto a numerical estimate of the *degree of inquietude* of the needle, by noting the elongation of its oscillatory movements. We found the ordinary diurnal march of the needle so quiet, that among 1500 results drawn from 6000 observations, from the middle of May 1806 to the end of June 1807, the oscillations were mostly only of half a scale division, or 1′ 12″. The needle was often quite still, or moving only 0·2 or 0·3 of a scale division during very tempestuous and rainy weather; but on the arrival of the *magnetic storm*, of which the more intense and later

manifestation is the Aurora or polar light, the oscillations were from 14 to 38 minutes of arc, each oscillation being performed in from $1\frac{1}{2}$ to 3 seconds of time. On many occasions the magnitude and inequality of the oscillations, which extended far beyond the limits of the divided scale on one or other, or on both sides, made any observation impossible.(169) For example, on the night of the 24th of September, 1806, this was uninterruptedly the case from 14h. 40m. to 15h. 32m., and again for the still longer interval from 15h. 57m. to 17h. 4m.

Most often in magnetic storms (the "unusual" or "larger magnetic disturbances") the middle point of the arcs of oscillation was in course of constant though unequal progress to one or the other side, *i. e.* east or west; but in other and more rare cases, extraordinary oscillations were remarked without any increase or decrease of the declination,—that is to say, without displacement of the middle point of the oscillations from its normal place at the particular hour. After a long time of comparative repose, we sometimes saw very unequal movements take place suddenly (describing arcs of from 6 to 15 minutes, the different magnitudes being either alternately or irregularly intermixed), and then the needle would as suddenly become calm again. It was at night that such alternations of total repose, and violent fluctuation without progressive movement towards either side, were particularly striking.(170) Another peculiar modification of these movements should be mentioned; it occurred very rarely, and consisted in a particular kind of affection of the inclination of the north end of the needle, continuing for 15 or 20 minutes of time, with only very moderate horizontal fluctuations, or even with an entire absence of any. In the registers of the British observatories,

where all the attendant circumstances are so diligently noted, I find this purely vertical trembling ("constant vertical motion, the needle oscillating vertically") mentioned three times in the case of the declination magnet at Hobarton;(171) and frequent notices of the vibration of the vertical and horizontal force magnets at Toronto when no change took place in their mean readings.

It appeared to me, that the average hour of the occurrence of the larger magnetic disturbances at Berlin was the third hour after midnight, and that they ceased most usually at 5 A.M. We observed small disturbances in the afternoon between 5 and 7 P.M., often on the same days in the month of September when there ensued after midnight such magnetic "storms," that the magnitude and rapidity of the oscillations made any reading, or any appreciation of the middle point of the oscillation, impossible. I was very early so convinced that the magnetic storms occur in groups, returning on successive nights, that I announced this peculiarity to the Berlin Academy, and invited friends to visit me at predetermined hours, to enjoy the sight of the phænomenon: and our expectations were more often realised than disappointed.(172) Kupffer, during his journey to the Caucasus in 1829, and afterwards Kreil, in his valuable Prague observations, corroborated this disposition of the magnetic storms to return at the same hours.(173)

Since the establishment of the British Colonial magnetic observatories, the rich mass of materials which they have afforded, and the able treatment of these materials by Colonel Sabine, have caused the facts relating to the extraordinary disturbances of the declination, which I had recognised only in a general manner in my equinoctial and solstitial observations of 1806, to become one of the most

important of the acquisitions which have been gained towards a complete knowledge of terrestrial magnetism. Sabine has distinguished the disturbances, in the results of both hemispheres, into classes, according to the hours of their occurrence, whether in the day or in the night,—the seasons of the year,—and the direction in which they deflect the needle, whether to the east or to the west. At Toronto and at Hobarton, the disturbances were twice as great, both in frequency and value, in the night as in the day,[174] as in the older observations at Berlin; but in from 2600 to 3000 disturbances at the Cape of Good Hope, and more particularly at St. Helena, the direct contrary was the case, as shown by a similarly thorough investigation of the phænomena at those observatories by Captain Younghusband. At Toronto, the principal disturbances were observed, on the average, from midnight to 5 in the morning; occasionally only they were observed earlier, between 10 P.M. and midnight,—predominating, therefore, in the night at Toronto as at Hobarton. After a very laborious and well-devised examination of 3940 disturbances (of the declination) at Toronto, and 3470 at Hobarton, taken from six years of observation, 1843—1848, (the observations selected as disturbed making the ninth and tenth portions of the entire mass), Sabine has drawn the conclusion,[175] that the disturbances belong to a peculiar class of periodically recurring variations, following recognisable laws dependent on the position of the Sun in the ecliptic, and on the diurnal rotation of the Earth upon its axis; that they ought no longer to be called *irregular* movements; and that we may distinguish in them, together with a particular local type, general processes affecting the whole globe. In regard to the different amount of disturbance in different years, the same years in which the disturbances

were most frequent at Toronto in the northern hemisphere were also those in which they were most numerous at Hobarton in the southern hemisphere,—and that nearly in an equal degree. In regard to the differences in different parts of the year, the disturbances were, on the whole, twice as numerous at Toronto in the summer months of the station (April to September), as in its winter months (October to March). (In my Berlin observations of 1806 the greatest number in any month belonged to the month of September at the time of the autumnal equinox.) ([176]) They are more rare in the winter months of each station; *i. e.* more rare from November to February at Toronto, and from May to August at Hobarton. The times of the Sun's passage over the equator are also, according to Captain Younghusband, in a high degree remarkable for the greater frequency of disturbances at St. Helena and the Cape of Good Hope. In the higher latitudes of both hemispheres the disturbances are less frequent in the winter than in the summer, *i.e.* less frequent at Hobarton from May to September, and at Toronto from November to March.

A most important feature in the phænomenon also first made known by Sabine, is the regularity, in both hemispheres, of the disturbances in the direction of the needle either to the east or to the west. At Toronto, where there was a small west declination (1° 33′), the number of disturbances which deflected the needle to the east preponderated in summer (June to September), and that of those which deflected it to the west, in winter (December to April); and this in no inconsiderable ratio—411 : 290. The case is similar at Hobarton, according to the seasons of the southern hemisphere. In the winter months of that station (May to August) the disturbances are strikingly less fre-

quent.(177) The analysis of six years of observation at the two opposite stations of Toronto and Hobarton, has conducted Colonel Sabine to the remarkable result,—that in both hemispheres, not only the number of disturbances, but also the amount of average diurnal variation from the mean or normal place and the latter (obtained from all the observations of the year omitting the 3469 storms), increased gradually in the five years from 1843 to 1848, from 7′·65 to 10′·58; and that simultaneously with this a similar increase could be traced in the variations of the inclination and of the total force. This result gained a yet higher degree of importance when he found both a confirmation and a generalisation of it in Lamont's detailed investigation of Sept. 1851, "on a decennial period presented by the diurnal movement of the declination needle." According to observations at Göttingen, Munich, and Kremsmünster,(178) the mean amount of the diurnal variation of the declination was at a minimum from 1843 to 1844, and at a maximum from 1848 to 1849. After the declination has increased five years, it decreases for the same number of years, as is shown by a series of observations which lead back to a maximum in 1786½.(179) In order to find a general cause for such a periodicity in all the three elements of terrestrial magnetism, one is inclined to have recourse to some cosmical connection. Such a connection is found, according to Sabine's conjecture,(180) in the variations which take place in the photosphere of the Sun, *i. e.* in the luminous gaseous envelopes of the dark solar orb; for, according to Schwabe's researches, extending over a long series of years, the periods of greatest and least frequency of the solar spots coincide perfectly with those discovered in the variations of terrestrial magnetism.

Sabine was the first to call attention to this accordance or coincidence, in his paper presented to the Royal Society of London in March 1852. Schwabe said, in a passage with which he enriched the astronomical portion of my Cosmos, "There is no doubt that, at least from the year 1826 to 1850, the solar spots have shown a period of about ten years with maxima in 1828, 1837, and 1848, and minima in 1833 and 1843."(181) Sabine also sagaciously adduces, in confirmation of the powerful direct influence of the Sun upon terrestrial magnetism, the remark that in *both* hemispheres the period when the intensity of the Earth's magnetic force is greatest, and the direction of the needle most near to the vertical, is in the months from October to February, which is just the period when the Earth is nearest to the Sun, and is moving with the greatest velocity in its orbit. (182)

The simultaneity of many magnetic storms, apparently propagated instantaneously between places many thousand miles apart, and even almost round the entire globe (as on the 25th of September, 1841, between Canada, Bohemia, Cape of Good Hope, Van Diemen Island, and Macao), has been already treated of in Vol. i.(183) : examples were also cited of cases in which the perturbation appeared to have a more local character, extending from Sicily to Upsala, but not beyond Upsala to Altyn or Lapland. In the simultaneous observations of declination arranged by Arago and myself in 1829, to be made with similar instruments of Gambey's at Berlin, Paris, Freiberg, St. Petersburg, Kasan, and Nicolaieff, some considerable perturbations showed themselves at Berlin which did not extend to Paris, or even to a mine at Freiberg where Reich was making subterranean magnetic observations. Great deflections and oscillations of the needle accompanying

Auroras at Toronto, were synchronous with magnetic storms at Kerguelen Island in the southern hemisphere, but not at Hobarton. Considering the all-pervading character of magnetic as well as gravitating force in all matter, it seems indeed difficult to form a clear conception of any obstacles to the propagation of magnetic force through the globe, analogous to those which impede the undulations of sound, or those which intercept earthquake waves, so that at some nearly adjacent places the earthquake shocks have never been known to occur simultaneously. ([184]) May it be that the intersection of magnetic impulses may oppose their propagation?

I have described both the regular and the *seemingly* irregular movements presented by horizontally-suspended needles. Having examined the regular periodically-recurring march of the needle, and found the mean direction around, or, in other words, on either side of which the oscillations have taken place—say from one solstice to the return of the same solstice in the following year—this mean direction is the magnetic meridian of the place for the given year. The comparison of the angle made by the magnetic meridians of different places on the globe with their geographical meridians, first led to the recognition of "variation-" (*i. e.* declination-) lines of strikingly different values (which Andrea Bianco in 1436, and Alonso de Santa Cruz, the cosmographer of the Emperor Charles V., thus early attempted to enter on charts); and subsequently to the happily devised generalisation of *isogonic* curves, or lines of equal declination, to which the grateful recollection of English navigators long gave the historic name of "Halleyan lines." Among these lines of various curvature, running

in some places almost parallel to each other, more rarely returning into themselves, and, where they do so, forming closed systems of an oval form, especial attention has been given to the lines on which the declination is 0°, at all points of which the direction of the compass-needle is that of true or geographical north and south, — and in receding from which lines on either side, opposite declinations are found (*i. e.* east declinations on one side, and west on the other), the amount of declination increasing unequally with increased distance. ([185]) I have shown elsewhere how Columbus's first discovery of a "line without variation" in the Atlantic Ocean, on the 13th of September 1492, gave an impulse to the study of terrestrial magnetism, – which, however, for two centuries and a half was directed solely towards the improvement of ships' reckonings.

Greatly as in modern times the higher scientific training of navigators, and the improvements which have taken place in instruments and in methods, have extended our knowledge of detached *parts* of the lines of no declination in the north of Asia, the Indian Archipelago, and the Atlantic Ocean, yet in this department of knowledge, where the want of a general or cosmical view is felt, there is still reason to complain of slowness of progress, and absence of the desired completeness in the research. I am aware that a countless number of observations, made during *accidental* passages across the lines of no declination, have been entered into ships' journals; but comparison and combination of the materials are wanting; — nor can the results of such a labour (even supposing it to be undertaken), either on this subject, or on that of the position

of the line of no inclination for a definite epoch, have all the desired importance, until ships charged with the sole duty of tracing these lines uninterruptedly throughout their course shall be sent contemporaneously to different seas. I here renew a solicitation to which I have repeatedly permitted myself to give free expression. (186) For systematic investigations in terrestrial magnetism it is of primary importance that the determinations should be contemporaneous.

According to our present general knowledge of the "lines of no declination," instead of four such lines running as meridians from pole to pole, as was supposed at the end of the 16th century, (187) there appear to be three very differently shaped systems, using the word "system" in this case to denote a group of isogonic lines which include a line of no declination unconnected, so far as we know, with any other such line. Of these three systems, which I shall presently describe separately, the Atlantic one consists simply of a line of no declination directed from SSE. to NNW., and recognised as extending from the 65th degree of south to the 67th degree of north latitude. The second system is situated fully 150 degrees to the eastward of the first (looking in both cases only at the points of intersection of the lines of no declination with the geographical equator); it is the broadest and most complex system, and occupies the whole of Asia and Australia. It has one summit directed to the north, and one to the south: in the north-eastern part the line of no declination takes an oval shape, and returns into itself, surrounding lines of successively and rapidly increasing declination. The east and west sides of this

ellipse, like the Atlantic of 0°, have a direction from south to north, and between the Caspian and Lapland, from SSE. to NNW. The third system, that of the Pacific Ocean, which has been least examined, is less than the others, and is almost entirely confined to the south of the geographic equator: it forms a closed oval of concentric lines of successively decreasing east declination. On the African continent, inferring from what we know of the declination on its coasts, ([188]) there are only lines having a west declination of from 6° to 29°; the Atlantic line of no declination quitted the south point of Africa (Cape of Good Hope), according to Purchas, as early as 1605, moving from east to west. As far as we are acquainted with the facts, there is not in the interior of central Africa an oval group of concentric declination lines similar to that in the Pacific.

The Atlantic part of the American curve of no declination has been accurately determined and laid down in an excellent work by Colonel Sabine, "On the Declination Lines over the Atlantic Ocean, between the parallels of 60° north and 60° south latitude, for the year 1840," based on 1480 observations either made in that year, or reduced to it by careful allowance for secular change. Tracing this line of no declination from its most southern known point (in lat. 70° S., where it was found in about 19° W. long.), ([189]) it runs NNW. to 3° west of Cook's Sandwich Land, and to 9½° east of South Georgia; it then approaches the Brazilian coast, which it enters at Cape Frio, two degrees east of Rio Janeiro; continues within the South American continent to S. lat. 0° 36′, and quitting the continent

again a little to the east of Para, near Cape Tigioca, at one of the mouths of the Amazon (Rio de Para), it cuts the geographic equator in 48° 30′ W. long., and runs at a distance of nearly ninety miles from the coast of Guyana up to 5° of North latitude, from whence, following the curve of the smaller West-Indian Islands, it ascends to 18° N. lat., and passes from thence to the coast of North Carolina, which it enters in lat. 34° 50′, W. long. 76°·30′, near Cape Lookout, south-west of Cape Hatteras. In the interior of North America this curve continues its north-west direction to lat. 41½°, long. 80°, towards Pittsburgh, Meadville, and Lake Erie. There is reason to suppose that it may already have moved, in some parts of its course, more than a degree to the west since 1840.

The Australo-Asiatic curve of no declination,—if, with Erman, we regard the line which at Kasan trends northwards to Archangel and Russian Lapland, as part of the same line which passes the Moluccas and the Sea of Japan, — can scarcely be traced in the southern hemisphere so far as the 62d degree of latitude. Its most southern known point is more to the west of Van Diemen Island than was previously supposed. The three points at which Sir James Ross, (190) in his antarctic voyages of discovery, crossed it in 1840 and 1841, in the parallels of 62°, 54½°, and 46°, were all between the longitudes of 133°·20′ and 135°·40′ East, showing an almost north and south direction in this part of its course. It then traverses Western Australia, entering the south coast of Nuyts Land (about ten degrees west of Adelaide), and quitting the northern coast near Vansittart River and Mount Cockburn. From hence it

enters the Indian Archipelago, where the declination, inclination, total force, and line of minimum intensity of the total force, and of maximum intensity of the horizontal force, have all been investigated with admirable exactness, in 1846—1848, by Captain Elliot. Here the line of no declination passes immediately to the south of the Island of Flores, through the small "Sandal Wood" Island, (191) and from 120° to 94° E. long. in a due east and west direction;—as, indeed, Barlow had laid it down correctly sixteen years before. From the last-named meridian, and about $9\frac{1}{2}°$ S. lat., it seems probable—judging by the line of 1° E. declination which Captain Elliot has traced up to Madras—that the line of no declination takes a new direction trending to the north-west. It is impossible at present to form any certain conclusion as to whether, in its further prolongation, it cuts the geographic equator in the meridian of Ceylon, and enters the continent of Asia either between the Gulf of Cambay and Guzerat, or further to the west in the Bay of Muscat, (192) and so is identical with the curve of no declination, (193) which appears to run to the southward from the shores of the Caspian;—or whether, on the contrary (as Erman thinks), it bends back to the east, and passes between Borneo and Malacca, and, ascending towards the north, reaches the Sea of Japan, (194) and enters North-eastern Asia through the Sea of Ochotsk. It is greatly to be regretted that the very numerous determinations which must have been obtained in the frequent navigation to India, Australia, the Philippines, and the north-east coast of Asia, have not yet been co-ordinated and rendered conducive to general views, by connecting the south of Asia with its

better magnetically explored northern regions, or to the solution of questions which have been raised since 1840. Not to mix the uncertain with the certain, I will therefore limit myself in the following description to the Siberian portion of the Asiatic continent, so far as it is known to us down to the parallel of 45° by the observations of Erman, Hansteen, Due, Kupffer, Fuss, and myself. There is no other part of the earth's surface on which magnetic lines could have been traced over so great an extent of continental territory,—a circumstance which appears to me of some importance, as it did long since to Leibnitz when speaking of the importance of the Russian dominions in Europe and Asia in reference to this subject. ([195])

Advancing from the west towards the east as the usual direction followed by European expeditions to Siberia, and commencing at the northern part of the Caspian Sea, we find that, at what may be termed a group of stations, viz. the little island of Birutschikassa at Astrachan, the Elton Lake in the Kirghis steppe, and Uralsk on the Jaik, — places situated between the latitudes of 45° 43′ and 51° 12′, and the East longitudes of 46° 37′ and 51° 24′, — the declination ranges from 0° 10′ E. to 0° 37′ W. ([196]) Further to the north this line of declination inclines rather more to the northwest, passing near Nishnei Novgorod, ([197]) — (in 1828, between Osablikowo and Doskino, in lat. 56°, long. 43°). It is prolonged towards Russian Lapland, passing between Archangel and Kola, or more exactly, according to Hansteen in 1830, between Umba and Ponoi. ([198]) In advancing eastward from this point, between the parallels of 50° and 60°, it is not until we have traversed

nearly two thirds of the breadth of Northern Asia in this its widest part (a space now entirely occupied by east declination), that we arrive at a line of no declination, which, at the north-eastern part of Lake Baikal, west of Viluisk, ascends towards a point situated in the meridian of Iakutsk, or in about 130° E. long., and as much as 68° N. lat., from whence it redescends towards Ochotsk (in 143° 10′ E. long.), forming the outermost line of the eastern side of the oval-shaped group of concentric declination-lines which has been before alluded to, and then crosses the Kurile Islands, passing south into the Sea of Japan. The isogonic lines from 5° to 15° east declination, which occupy the space between the east and west Asiatic lines of no declination, are all concave towards the north. Their greatest curvature falls, according to Erman, in long. 80°, or in a meridian nearly intermediate between Omsk and Tomsk, and not very different from that of the southern point of the peninsula of Hindostan. The longer axis of the closed oval group extends through twenty-eight degrees of latitude, or about to the Corea.

A similarly shaped group or system of declination-lines, but of larger dimensions, presents itself to our observation in the Pacific. The closed curves there form an oval extending from 20° N. to 42° S. latitude. The principal axis is situated in 130° W. long. The most remarkable feature of distinction between this singular group (the greater portion of which is in the southern hemisphere, and which is wholly oceanic), and the previously described continental group of Eastern Asia, is that in the Pacific group it is East declination which decreases, while in the Asiatic oval it is West

declination which increases, in penetrating towards the interior of the oval. In the Pacific oval we only know at present declinations of from $-8°$ to $-5°$. May there be, more in the interior, another line of no declination enclosing a space of westerly declination?

The curves of no declination, like all the magnetic lines, have each their own proper history, although it can only in any case be very imperfectly traced back beyond two centuries. We possess, indeed, detached materials of an earlier date, going back even to the 14th and 15th centuries. Hansteen has here also the great merit of having assembled and compared the data with great judgment. It would appear as if the north magnetic pole were moving from west to east, and the south magnetic pole from east to west: but we know from exact observations, that different portions of the isogonic curves advance at very unequal rates of progression,— that where they were once parallel, they are now no longer so, — and that adjoining regions, over which declinations of opposite denominations prevail, enlarge and contract in very different directions. The lines of no declination in Western Asia and the Atlantic Ocean advance from east to west. The former (or West Asiatic) passed through Tobolsk in about 1716; Catharinenburg (in Chappe's time) in 1761; and between Osablikowo and Doskino (not far from Nishnei Novgorod) in 1829; so that in 113 years it had advanced $24\frac{3}{4}°$ towards the west. If the line of no declination of the Azores, determined by Columbus on the 13th of September 1492, was the same line which, according to the observations of Davis and Keeling, passed in 1607 through the Cape of Good Hope, (199) and the same

which we now see in the western part of the Atlantic Ocean, passing from the mouth of the Amazons to the coast of North Carolina; — we are led to ask what has become of the line of no declination which passed in 1600 through Königsberg; in 1620? through Copenhagen; in 1657 — 1662 through London (and yet, according to Picard, only in 1666 through Paris, which is to the east of London); and rather before 1668 through Lisbon? (200) There are particular parts of the globe in which, throughout a long interval of time, no secular change has been remarked. Sir John Herschel has called attention (201) to such a long period of suspension of change in Jamaica, as Euler (202) and Barlow (203) had already done to a similar one in South Australia.

Polar Light, or Aurora.

I have treated in detail the three elements of Terrestrial Magnetism, or the magnetic "Declination," "Inclination," and "Force," in their connection with geographical position, and their variations according to hour and season. The "extraordinary disturbances," or perturbations, which were first observed in the declination, are, as Halley conjectured, and as Dufay and Hiorter recognised, partly the precursors and partly the accompaniments of the magnetic polar light, or aurora borealis or australis. In the "Representation of Nature" contained in the first volume of my work, I have discussed with some degree of fullness the peculiarities belonging to this "telluric luminous process," often so remarkable by its beautiful display of colours; and

more recent observations have in general been favourable to the views there expressed, in which "the aurora was not regarded as the cause of the disturbance in the equilibrium of the distribution of the earth's magnetism, but rather as the result of a state of telluric activity excited to the point of the production of a luminous phænomenon; an activity manifesting itself on the one hand by the fluctuations of the needle, and on the other by the appearance of the brilliant auroral light." In this view the polar light might appear as a kind of silent discharge,—as the termination of a magnetic storm. In electric storms the equilibrium of the disturbed electricity is also restored by a development of luminosity,—by the flashing lightning, accompanied by the noise of thunder. In a phænomenon so complex and mysterious, the repeated bringing forward of a determinate hypothesis ([204]) has at least the advantage of inviting a more sustained and careful observation of all those details by which it may be confuted or corroborated.

In dwelling on the purely objective description of these phænomena, and availing myself principally of the fine uninterrupted eight-months series of examinations for which we are indebted to the sojourn of several distinguished physicists ([205]) in the extreme north of Scandinavia in 1838—1839, I would direct the attention in the first place to the dark misty wall which rises gradually on the horizon, and is called the "black segment of the aurora borealis." ([206]) The blackness, as Argelander remarks, is not a result of contrast, for it is sometimes seen before the luminous arch begins to bound it:—it is a process going forward in a part of the atmosphere, for hitherto we have had no evidence of

any admixture of foreign matter causing the darkness. The smallest stars are perceived by the telescope in the dark segment as well as in the coloured and bright parts of the fully developed aurora. The black segment seems to be much more rare in the higher than in the middle latitudes: the observers above spoken of did not see it once during the whole of February and March, although auroras were abundant and the sky extremely serene; nor did Keilhau see it once during an entire winter passed by him at Talving in Lapland. By exact determinations of stars' altitudes, Argelander has shown that they are not in the least influenced by any part of the aurora. Even out of the segment there appear, although rarely, black rays, which Hansteen ([207]) and I have more than once seen stream upwards: together with these, there appear roundish black patches, enclosed by luminous borders, to which Siljeström has given especial attention.([208]) Also, in that rare phænomenon, the auroral corona, which, by the effect of linear perspective projection, corresponds in altitude to the magnetic inclination of the place, the middle of the corona is mostly a very deep black. Bravais regards both this and the black rays merely as optical effects of contrast. Several luminous arches often appear at the same time—in rare cases as many as seven or eight, advancing parallel to each other towards the zenith; sometimes they are entirely absent. The bundles of rays and luminous streamers assume the most varied forms: curved, wreathed like garlands, indented, hooked, in waving sheets, or like ships' ensigns floating in the breeze. ([209])

In high latitudes, "the usually prevailing colour of the polar light is white, milk-white indeed when the

intensity is feeble. As the tone of colour becomes more vivid it passes into yellow, the middle of the broad beam becoming full yellow, and detached red and green appearing at either margin. When the beams are long and narrow, the red is above and the green below. When the motion is lateral from left to right, or *vice versâ*, the red always appears on the side towards which the movement is directed, and the green remains behind." Of these complementary colours, green and red, it is very rare to see one without the other. Blue is not seen at all; and a dark red, resembling the reflection of a fire, is so rare in the North, that Siljeström only saw it once.([210]) The illuminating power of the aurora borealis never quite equals, even in Finmarken, that of the full moon.

The connection so long maintained by me as probable, of the polar light with the formation of the "smallest and most attenuated cirrus, or light fleecy clouds, the parallel equidistant lines of which most often follow the direction of the magnetic meridian," has indeed found in more recent times many defenders; but whether, as the northern traveller Thienemann and Admiral Wrangel think, these lines of cirri form the substratum of the aurora, or whether they are not rather, as has been the opinion of Franklin, Richardson, and myself, the effects of a meteorological process accompanying and produced by the magnetic storm, still remains undecided. ([211])

Besides the general conformity of the direction of the magnetic declination with that of the regularly arranged and very delicate cirrus ("bandes polaires"), my attention was strongly attracted, both in Mexico in 1803 and

in Asia in 1829, by the rotation, or movement in azimuth, of the points of convergence. When the phænomenon is very complete, the two apparent points of convergence do not remain fixed, the one in the north-east, the other in the south-west, (in the direction of the line which unites the highest points of the nocturnally bright auroral arches,) but the line turns, so as gradually to bring those points more towards the east and west.([212]) A perfectly similar movement in the line which joins the summits of true auroral luminous arches (the ends of feet changing in azimuths from E.—W. towards N.—S.) has been observed with great exactness more than once in Finmarken. ([213]) In the view here taken, the cirri arranged as "polar bands" correspond in position to the "streamers" or "bundles of rays" which shoot upwards towards the zenith from the auroral arch of which the span is most often E.—W., and are not therefore to be confounded with the arch itself; the latter was once seen by Parry in the arctic regions during daylight, it having continued visible after a night of aurora. A similar phænomenon was witnessed on the 9th of September 1827 in England. It was even possible to recognise the streamers ascending from the arch in daylight.([214])

It has been often stated that a perpetual evolution of light, or aurora, takes place around the north magnetic pole. Bravais, who observed without intermission for 200 nights, in which 152 auroras admitted of exact description, does indeed assure us that nights without any aurora are very exceptional; but yet he sometimes either saw no trace of auroral light during a very clear night, and with an uninterrupted horizon, or the "mag-

netic storm" only began very late. The greatest absolute number of auroras were seen towards the latter part of the month of September, and as March also showed relative frequency as compared with February and April, we may surmise here also, as in other magnetic phænomena, a connection with the equinoxes. In addition to instances of aurora borealis seen in the southern hemisphere in Peru, and of aurora australis seen so far north as Scotland, I may mention a coloured aurora borealis seen and observed for two hours by Captain Lafond in the 'Candide' on the 14th of January 1831, south of New Holland, in latitude 45°. ([215])

The sound sometimes attributed to the aurora has been negatived by the French physicists, and by Siljeström at Bossekop, ([216]) as decidedly as by Thienemann, Parry, Franklin, Richardson, Wrangel, and Anjou. Bravais estimated the elevation or height of the aurora above the earth at 100,000 metres, or more than fifty miles; while a very meritorious observer, Mr. Farquharson, had estimated it as only four thousand feet. The grounds on which all these estimations are based are exceedingly uncertain, and are liable to be altogether vitiated as well as by optical illusions, as by unproved assumptions of the actual identity of a luminous arch seen simultaneously from two distant places. On the other hand, the influence of the aurora on the declination, inclination, and intensity, both horizontal and total, of the magnetic force (on all the elements, therefore, of the earth's magnetism), is undoubted, although very unequal at different stages of the phænomenon, and in the effect produced on the different elements. The most complete observations on this subject are

those of Siljeström [217] and Bravais (1838—1839) in Lapland, and those at Toronto in Canada (1840—1841), discussed with much perspicacity by Sabine. [218] In our concerted simultaneous observations made at Berlin in Mendelssohn's and Bartholdy's garden, at Freiberg below the earth's surface, at Petersburg, Kasan, and Nicolaieff, a derangement of the magnetic declination was perceived at all the stations during an aurora seen at Alford in Aberdeenshire (lat. 57° 15′) on the 19th and 20th of September 1829; — and at those among them at which the other magnetic elements were also observed, the dip and force were also seen to be affected. [219] During the fine aurora borealis observed at Edinburgh by Professor Forbes, on the 21st of March 1833, the magnetic inclination in the mine at Freiberg underwent a remarkable decrease, and the declination was so disturbed that it was hardly possible to take any readings. A phænomenon which appears deserving of particular attention, is a decrease of the total magnetic force during increasing activity of the auroral process. The results obtained by Oltmanns and myself at Berlin, during a fine aurora borealis on the 20th of December 1806, [220] and which were printed in Hansteen's "Untersuchungen über den Magnetismus der Erde," have been corroborated by Sabine and by the French physicists in Lapland in 1838. [221]

As in the foregoing careful attempt at an account of the state of our positive knowledge in regard to the phænomena of terrestrial magnetism, I have limited myself to a simply objective representation, inasmuch as theoretical views drawn by inductive reasoning from analogies have not yet assumed a sufficiently satisfactory

form,—I have no less designedly avoided the attempt to infer geognostical connections between the direction of great mountain-chains or stratified rocks, and of the magnetic lines, more especially the isoclinal and isodynamic lines. I am far from denying the possible influence of cosmical primeval forces, of dynamic and chemical forces as well as of magnetic and electric currents, on the formation of crystalline rocks and the filling up of veins; (222) but seeing the progressive movement, accompanied by change of form, of all the magnetic lines, it cannot be supposed that the position which they may be found to occupy at any particular time, can throw any light on the relations of direction of mountain-chains upheaved at exceedingly remote but very different epochs, or on the foldings or corrugations then taking place in the gradually hardening, heat-exhaling crust of the earth.

There are indeed other relations, not affecting the earth's general magnetism, but only of a very partial and local character, subsisting between geognostic and magnetic phænomena, which may be called "mountain- or rock-magnetism." (223) I was much interested by these when examining in 1796 (previous to my departure for America) the magnetic serpentine rock of the Haidberg in Franconia, and they then gave rise in Germany to a good deal of literary debate. They present a series of problems very accessible to observation and experiment, in which there remains much to be determined. The intensity of the rock-magnetism may be tested in detached fragments of hornblende- and chloride-slate, serpentine, syenite, dolerite, basalt, melaphyre, and trachyte, by experiments of deflection and

vibration of magnetic needles. In this manner, by comparison of the specific weight, and by applying the microscope to finely pulverised portions, it may be decided whether the strength of the polarity does not often proceed less from the *quantity* of the interspersed grains of magnetic iron and iron oxide, than from the *relative position* of the grains. A more important question, however, in cosmical respects, and which was propounded by me long since in connection with the Haidberg, is: whether there are mountain-ridges in which an opposite polarity is found on the opposite sides? [224] An accurate astronomical determination of the magnetic axis of such a mountain would become of great interest, if after considerable intervals of time there should be recognised either an alteration in the direction of the axis, or an (at least apparent) independence of the three variable elements of the general magnetic force of the earth.

II.

Reaction of the interior of the earth on its exterior, showing itself, — (*a*) dynamically, by waves of agitation, or "earthquakes;" — (*b*) by the increased temperature of the water of springs, and the admixture of other substances, as salts and gases, in mineral and thermal springs; — (*c*) by the breaking forth of elastic fluids, accompanied at times by phænomena of spontaneous ignition (gas- and mud-volcanoes, burning naphtha, and salses); — (*d*) by the grand and powerful action of volcanoes proper, in which, (by permanent channels of communication with the atmosphere through fissures and craters), earths molten at profound terrestrial depths are erupted as glowing scoriæ, partly subjected, at the same time, to processes whereby they are changed into crystalline rocks, and partly poured forth in long narrow streams of lava.

In order to maintain, in accordance with the fundamental plan of my work, the connecting links uniting all telluric phænomena, and to preserve the representation of the concurrent action of forces in a single system, we must here recall how, beginning from the general properties of matter, and the three principal directions of their activity (attraction, light- and heat-exciting undulations, and electro-magnetic processes), the first division of the present volume treated of the magnitude, figure, and density of our planet; its internal distribution of heat; and its magnetic condition. The above-named classes of activity in the material universe (molecular and mass-attraction or gravitation, light- and heat-exciting

undulations, and electro-magnetic activity) are nearly allied manifestations (225) of one and the same primary force, among which the first is the most independent of diversity of substance. We have in all the above respects represented our planet in its cosmical relation to the central body of its system: its primitive internal heat, generated possibly by the condensation of a rotating nebulous ring, is modified by the solar action; and, as has been above stated, according to the latest hypotheses a periodical action is exercised on terrestrial magnetism by a particular condition of the Sun, manifested to us by the periodically varying frequency of the solar spots, or openings in the outer envelopes of the Sun.

This second division of the present volume will be devoted to the group of telluric phænomena which are attributed to the reaction, still going forward, of the interior of the earth on its exterior.(226) I designate the whole of these phænomena by the general name of volcanism or volcanicity, and I regard it as an advantage not to divide effects having the same causal connection, and differing only by the strength of the manifestation of the acting force, and by varieties in the complication of the physical processes involved. In this generality of view, small and apparently insignificant phænomena acquire a greater significance. An observer not scientifically prepared, who visits for the first time a basin filled by a hot spring, and sees ascend from it gases which extinguish the flame of a candle, or walks between rows of variable cones of mud-volcanoes hardly exceeding in height his own stature, would not divine that the place now thus harmlessly occupied has been repeatedly the scene of fiery eruptions as-

cending to the height of many thousand feet, and that the same internal force is at work as that which gives rise to colossal craters of elevation, and even to the mighty devastating, lava-pouring volcanoes of Etna and the Peak of Teneriffe, and to those of Cotopaxi and Tunguragua from which scoriæ are ejected.

Among the manifold and cumulative phænomena of the reaction of the interior against the external crust, I will first consider separately those whose essential character is simply dynamical, and which consist of undulations of the solid strata, — being a volcanic activity not necessarily accompanied by chemical alteration of substances, or by the eruption or production of any fresh substance. In the other phænomena of the reaction of the interior against the exterior, — in gas- and mud-volcanoes, in burning naphthas and salses, and in the great burning mountains which were first, and for a long time exclusively, termed volcanoes, — there are always present, the production of some fresh substance (gaseous or solid), processes of decomposition and evolution of gases, and the formation of rock from particles arranged in crystalline order. These are, speaking in the most general terms, the distinctive marks or signs of the volcanic vital activity of our planet. In so far as this activity is to be principally ascribed to the high temperature of the interior of the earth, it is probable that all heavenly bodies which have been condensed from a gaseous to a solid state, with an accompanying enormous extrication of heat, must present analogous phænomena. The little that we know of the configuration of the Moon's surface seems to afford indications (227) in correspondence with this

view. We can imagine upheavings and formative activity in the production of crystalline rocks from a molten mass, even in a body supposed to be destitute of air and water.

A genetic connection between the classes of volcanic phænomena which have been mentioned is indicated by many and various traces of simultaneity, and accompanying transitions of the simpler and less powerful actions into the more energetic and complicated ones. The sequence in which I have arranged my materials, in the mode of presentation which I have selected, is justified by considerations of this nature. The magnetic activity of our planet (of which the seat is not, indeed, to be looked for in the molten interior, although, according to Lenz and Riess, iron in a molten state is capable of acting as the conductor of an electric or galvanic current,) produces, when enhanced, a development of light at the magnetic poles of the earth, or at least in their vicinity. The first division of the present or telluric volume of my work closed with this terrestrial luminosity. I place at the opening of the second division, or next in succession to this phænomena of a light-exciting undulation of the ether caused by magnetic forces, and first among volcanic phænomenon, that class of volcanic activity which in its essential manifestations acts only, as does the magnetic activity, dynamically: exciting motions or undulations in the solid crust of the earth, not producing or altering substances. Other not essential, but in this point of view secondary, phænomena (flames rising during earthquakes, eruptions of water, and evolution of gas (228) following after the earthquake) recall to the mind the phænomena of thermal waters

and salses. Salses sometimes show outbursts of flames, visible to distances of very many miles, and rocks torn from internal depths hurled into the air and scattered around.(229) These, as it were, prepare the way for the grand phænomena of volcanoes proper, which in turn, in the intervals between distant epochs of eruption, exhale, like salses, only aqueous vapours and gases from fissures. Thus striking and instructive are the analogies presented in different stages by the gradations of volcanism.

a. *Earthquakes.*

(Extension of the Representation of Nature, in Kosmos, Bd. I. S. 210—225; Engl. Vol. I. p. 191—205.)

Since the publication of the first volume of the present work (in 1845), and of the general description there given of earthquake phænomena, the obscurity prevailing respecting their seat and their causes has been but little diminished; but by the labours of (230) Mallet (1846) and Hopkins (1847) some valuable light has been shed on the nature of the movement, the connection of operations apparently diverse, and the separation to be made between physical and chemical processes, associated or occurring simultaneously. Here, as elsewhere, advantage cannot fail to be derived from the application of mathematical reasoning, as in the precedent set by Poisson. In theoretical considerations on the dynamics of earthquakes, the analogies between the undulations of solid bodies, and the atmospheric waves of sound, to which Thomas Young had called attention, (231) are particularly adapted to lead to more simple and more satisfactory views.

Change of place, agitation, uplifting, and the production of fissures, mark the essential character of the phænomenon. We must distinguish between the acting force which gives the first impulse to the vibration, and the constitution, propagation, and enhanced or diminished intensity of the agitation-wave. In the "Representation of Nature," I described those effects which present themselves immediately to the senses, and which I had myself the opportunity of observing for so many years on the sea, on sea-like plains (the llanos), on elevations of from eight to sixteen thousand feet, on the margin of the craters of active volcanoes, and in granitic and mica-slate districts distant about twelve hundred geographical miles from any fiery eruption, — in districts where at particular periods the inhabitants no more count the number of earthquake shocks than we in Europe count the number of showers of rain, — where Bonpland and myself, in journeying through the forest, had to dismount from our mules on account of their becoming unruly from uneasiness at the earth trembling uninterruptedly beneath their feet for fifteen or eighteen minutes. By being so long habituated to these phænomena, (an advantage shared subsequently in a still higher degree by Boussingault,) one becomes better disposed for calm and accurate observation, for collecting and collating with critical care, at the time and on the spot, various and perhaps discordant accounts, and better prepared for learning what have been the circumstances attendant on great changes of the surface, of which fresh traces are seen. Although, when we were on the spot, five years had elapsed since the dreadful earthquake of Riobamba, by which, on the 4th of February 1797,

more than 30,000 human beings lost their lives in the course of a few minutes, (232) we still saw the once-moving cones of Moya (233) which had been then protruded from the ground, and the combustible substance of which they consisted employed in the huts of the Indians for cooking. I could describe changes of surface resulting from that catastrophe, quite analogous, on a larger scale, to those presented by the celebrated Calabrian earthquake (February 1783), and the accounts of which were long declared to be incorrect and exaggerated, because not explicable by too hastily formed theories.

Since, as I have already said, the considerations respecting the cause of the impulse to motion ought to be carefully separated from those which relate to the nature and the propagation of the waves of motion, the subject is thereby divided into two classes of problems of very unequal accessibility. In the first, as in so many cases where we desire to ascend to the higher links in the chain of causation, we cannot, in the present state of our knowledge, look for any generally satisfactory results. Nevertheless, while our efforts are directed to the discovery of laws in phænomena which we are unable to make the subject of actual observation, great cosmical interest attaches to our at the same time keeping constantly in view the different modes of genetic explanation which have been put forward as probable. The greater part of these (as in regard to all volcanic action or volcanicity) relate, under various modifications, to the high temperature and to the chemical constitution of the molten interior of the earth; one other most recently proposed mode of explanation of earthquakes in trachytic

regions is furnished by geological conjectures respecting the non-connection of volcanically upheaved masses of rock. I have brought together the following brief notices of the different views which have been taken of the possible nature of the first impulse in earthquake movements:—

In one of these views the interior of the earth is regarded as being in a state of igneous fluidity;—the result of the process of formation of planets from a gaseous state, whereby, in the transition from fluid to solid, great disengagement of heat took place; the external strata, by radiation of their heat into space, having been the first to cool down and solidify. The unequal ascent of elastic vapours (formed at the limits between the fluid and solid, either from the molten mass of the earth only, or by the penetration of sea-water), the sudden opening of fissures thereby occasioned, and the sudden approach of these vapours, formed at great depths, and having therefore great heat and tension, to the higher rocky strata nearer to the earth's surface,—are supposed to occasion agitation, and to give the first impulse to the earthquake-wave. An auxiliary influence, due to a non-telluric cause, is supposed to exist in the attraction of the moon and sun ([234]) acting on the fluid molten surface of the earth's nucleus, whereby there must arise increased pressure,—either immediately, against a solid superincumbent rocky vault,—or mediately, where in subterranean basins the solid is separated from the liquid molten mass by elastic vapours.

In another view the nucleus of our planet is regarded

as consisting of unoxidised masses of the metallic bases of earths and alkalies; and it is supposed that water and air gain access to these and thus that volcanic activity is excited. Volcanoes do, indeed, send forth great quantities of aqueous vapour into the atmosphere; but the hypothesis of a penetration of water to the volcanic hearth would have to encounter great difficulties in respect to the mutual pressure ([235]) of the external column of water and the internal lava; and the absence during eruptions, or at least the great rarity of ignited hydrogen, which is not adequately replaced by the formations of hydrochloric acid, ammonia, and sulphuretted hydrogen, ([236]) led the illustrious originator of this hypothesis spontaneously to relinquish it. ([237])

According to the third view, which is that of the accomplished South-American traveller, Boussingault, a want of continuity in the masses of trachyte and dolerite, of which the upheaved volcanoes of the chain of the Andes are composed, is regarded as a principal cause of many and very widely acting earthquakes in those regions. The colossal cones and dome-shaped summits of the Cordilleras are in this view supposed to have been by no means upheaved in a state of softness or semi-fluidity, but are regarded as consisting of enormous angular fragments, which have been pushed up and heaped one upon another. In the course of these operations it would necessarily have followed that, in the vast piles so formed, great intervals and cavities would have occurred, and that by subsidence, and by the occasional fall of imperfectly supported masses, commotions would ensue. ([238])

With greater clearness of view than is attainable in considerations respecting the nature of the first impulse (which, indeed, may be supposed to be of different kinds), we are able to reduce the action originated by it, *i.e.* the undulations of the earthquake-waves, to simple mechanical theories. As I have already remarked, this part of our knowledge of nature has latterly been very materially augmented. The undulations have been described in their progress and in their propagation through rocks of different degrees of density and elasticity; ([239]) and the causes of the diminution in their velocity of propagation by the occurrence of interruptions, reflexions, and interferences of waves ([240]) have been mathematically investigated. The apparently rotatory (or "vorticose") shocks, of which the obelisks in front of the convent of San Bruno, in the little town of Stephano del Bosco in Calabria (1783) present an example which has been much discussed, have been attempted to be reduced to rectilinear shocks. ([241]) Waves or undulations of air, of water, or of earth, do, indeed, all follow as respects space the same known dynamical laws; but the earth-waves are accompanied in their devastating action by phænomena which by their nature remain enveloped in greater obscurity, and belong to the class of physical processes. Such are exhalations or outpourings of vapours in a state of tension, gases, or (as in the small moving Moya-cones of Pelileo,) gritty mixtures of pyroxene crystals, carbonaceous matter, and silicious-shelled infusoria. These moving cones have overturned many Indian huts. ([242])

In the general Description of Nature in the first volume, in connection with the great catastrophe of

Riobamba, Feb. 4, 1794, many facts were collected by me on the spot from the lips of survivors, and with the most solicitous desire to elicit historic truth. Some of these, as has been already stated, were analogous to circumstances which took place in the great Calabrian earthquake of 1783; others, which were new, were especially characterised by an explosive action from below upwards. The earthquake itself was neither announced nor accompanied by any subterranean noise: but a prodigious noise, still designated simply as "el gran ruido," was first heard eighteen or twenty minutes later, and only under the two towns of Quito and Ibarra, at a distance from Tacunga, Hambato, and the chief theatre of devastation. In the history of catastrophes suffered by man, there is no other instance in which in the course of a few minutes, and in a thinly peopled mountainous country, so many thousand lives were lost by the production and passage of a few earth-waves, accompanied by the opening of fissures. In reference to this earthquake, of which the first accounts were given by the celebrated Valencia botanist, Don José Cavanillas, particular attention is further due to the following phænomena: — Fissures, which alternately opened and closed, so that persons partially engulfed were saved by extending their arms that they might not be swallowed up; portions of long trains of muleteers and laden mules (*recuas*), disappearing in suddenly opening cross fissures, whilst other portions, by a hasty retreat, escaped the danger; vertical oscillations, by the non-simultaneous rising and sinking of adjoining portions of ground, so that persons standing in the choir of a church, sixteen feet above the pavement of the street, found themselves

lowered to the level of the pavement without being thrown down; the sinking down of massive houses, (243) with such an absence of disruption or dislocation, that the inhabitants could open the doors in the interior, pass uninjured from room to room, light candles, and debate with each other their chances of escape, during two days which elapsed before they were dug out; lastly the entire disappearance of great masses of stones and building materials. The old town had possessed churches, convents, and houses of several stories, but in the places where they had stood, we found, on tracing out among the ruins the former plan of the city, only stone heaps, of from eight to twelve feet high. In the south-western part of old Riobamba (in the former Barrio de Sigchuguaica), we could distinctly recognise the signs of an explosion from beneath, the action of a force from below upwards. On the cone called Cerro de la Culca, which rises some hundred feet and appears above and on the north side of the Cerro de Cumbicarca, rubbish from the stone buildings lay mingled with the skeletons of men. Movements of translation in a horizontal direction, whereby avenues of trees were removed without being uprooted, or fields, bearing different kinds of cultivation, became intermixed, showed themselves repeatedly, both in Quito and in Calabria. A still more striking and complicated phænomenon was the finding articles belonging to one house among the ruins of others at a considerable distance — a discovery which gave rise to some lawsuits. Is it, as the inhabitants of the country believe, that the earth throws out again at one spot that which it has swallowed up at another? or, is it (notwithstanding the distance)

a simple transport over the earth's surface? As in nature effects are reproduced on the return of similar conditions, we ought unhesitatingly to mention even incomplete observations in order to direct the attention of future observers to special phænomena.

It is not to be forgotten that in most cases of the production of fissures, the earth-wave or undulation, by which the solid parts are agitated, is associated, according to my experience, with a concurrent action of very different forces, manifested in emanations of gases and vapours. If, in the undulatory movement, the extreme limit of the elasticity of the material (of the different kinds of rock or loose earthy strata) is overpassed, and rupture or separation ensues, elastic fluids in a state of tension may escape through the openings thus formed, bringing from the interior to the surface different substances, whose outburst may again become in turn a cause of fresh translatory movement. To the class of these merely accompanying phænomena of the primary agitation or earthquake, belongs the elevation of uncontestedly moving Moya cones; and, probably, also the transport of objects on the surface of the earth. (244) When, in the formation of great fissures, they close again in their upper portions only, the subterranean cavities thus produced may not only become the cause of fresh earthquakes,—inasmuch as, according to Boussingault's conjecture, ill-supported masses become in time detached, and, in sinking, cause commotion,—but we may also conceive it possible that in the fissures opened by earlier earthquakes, elastic fluids may become active in occasioning fresh earthquakes in places to which they formerly had no access. It would thus be the accompanying

or secondary phænomenon, and not the intensity of the undulation which had traversed a portion of the earth's crust, which would be the true occasion of the gradual, very important, and too little regarded extension of *circles of commotion*, or earthquake regions. ([245])

Manifestations of volcanic activity, to the lower gradations of which earthquakes belong, almost always comprise at once phænomena of movement, and physical production of substances. I have already noticed in the Description of Nature in the first volume, how there rise from fissures at a distance from any volcano:—water and hot steam; carbonic acid gas and other suffocating exhalations; black smoke, (as, for many days, at the rock of Alvidras in the Lisbon earthquake of Nov. 1, 1755); flame, sand, mud, and Moya with intermixed carbonaceous matter. The great geologist Abich has pointed out the connection between the thermal springs of Sarcin (about 5382 feet high), in Ghilan in Persia, on the road from Ardebil to Tabreez, and the earthquakes by which those highlands are visited at intervals of two years. In October 1848, an undulatory movement of the ground, which lasted an entire hour, obliged the inhabitants of Ardebil to leave the town, and at the same time the temperature of the springs, which is between 44° and 46° Cent. (111·2° and 114·8° Fahr.), rose for a whole month to scalding heat.([246]) Perhaps there is no place on the earth where, as Abich has told us, "the intimate connection of earthquakes producing fissures, with the phænomena of mud volcanoes, salses, inflammable gases permeating through loose soil, and petroleum springs, is more distinctly indicated, and may be more clearly recognised, than at

the south-eastern extremity of the Caucasus between Shemacha, Baku, and Sallian. It is that portion of the great Aralo-Caspian depression in which the ground is most frequently agitated." ([247]) When in Northern Asia, I was myself struck by the circumstance that the circle of commotion, or earthquake region, of which the district of Lake Baikal appears to be the centre, extends to the westward only as far as the easternmost part of the Russian Altai, as far as the silver mines of Riddersk, the trachytic rock of Kruglaia Sopka, and the hot springs of Rachmanowka and Arachan, but not to the chain of the Oural. Farther to the south, beyond the parallel of 45° lat., there is found in the chain of the Thian-schan, a zone running east and west, characterised by every kind of manifestation of volcanic activity. Not only does it extend from the "fire-district" (Ho-tscheu) in Tourfan through the small Asferah chain to Baku, and from thence past Mount Ararat to Asia Minor, but it is even thought that it may be traced between the latitudes of 38° and 40°, through the volcanic basin of the Mediterranean to Lisbon and the Azores. I have treated this important subject of volcanic geography in detail elsewhere.([248]) In Greece also, which has suffered more than any other part of Europe from earthquakes (Curtius, Peloponesos, Bd. i. S. 42—46), a countless number of warm springs, either still flowing or which have disappeared, have broken forth during earthquake shocks. A thermic connection of this kind was already pointed out in the remarkable book of John Lydus on earthquakes. (De Ostentis, cap. liv. p. 189, Hase.) The great natural event of the destruction of Helice and Bura, in Achaia (373 B. C.),

gave especial occasion to the formation of hypotheses respecting causal connection in volcanic activities. It was then that Aristotle originated the singular theory of the power of winds entangled in the bowels of the earth. (Met. II. p. 368.) The frequency of earthquakes in Greece and Lower Italy, by destroying the monuments of the most flourishing period of Art, has exercised a most unfavourable influence on the study of the Greek and Roman cultivation at different periods. Egyptian monuments also (for example a colossal statue of Memnon, 27 B. C.) have suffered from earthquake shocks, which, as Letronne has shown, were not so rare in the Valley of the Nile as has been supposed. (Les Statues Vocales de Memnon, 1833, p. 23–27, and 255.)

The considerations on which we have been dwelling will make it appear still more remarkable, that so many warm sanatory springs should have retained their composition and their temperature unaltered for centuries; and must therefore flow from fissures which have apparently undergone no changes either at their bottom or sides. Channels of communication opened with higher strata would have diminished, and with lower strata would have increased, the temperature of the spring.

At the great outburst of the volcano of Conseguina in the State of Nicaragua, on the 23rd of January 1835, the subterranean noise (249) (los ruidos subterraneos) was heard simultaneously in the island of Jamaica and on the highlands of Bogota (nearly 9000 feet above the sea); a distance greater than that between Algiers and London. I have already remarked elsewhere that at the eruption of the volcano in the Island of St. Vincent, on the 30th of April 1812, at two in the morning, a

noise similar to a cannonade, unaccompanied by any sensible earthquake movement, was heard over a space of 10,000 (German) geographical square miles, 15 to a degree. (250) It is well deserving of notice that when earthquakes are associated with subterranean noise, which is by no means always the case, the loudness of the noise does not increase with the strength of the earthquake. The most singular and wonderful phænomenon of the production of sound of which we have any record is still the subterranean and roaring "bramidos de Guanaxuato," from the 9th of January to the middle of the following month in 1784; respecting which I was able to obtain the first well assured intelligence from the lips of living witnesses, and from original official documents. (Vol. I. p. 196, and note 187.)

The velocity of earthquake propagation at the surface must be supposed to undergo a considerable modification from the very different densities of rocks, (granite and gneiss, basalt and trachytic porphyry, Jurassic limestone and gypsum,) and of alluvial soil or detritus, passed through by the undulation. It would, however, be exceedingly desirable to learn something as to the extreme limits between which the rates of velocity vary. It is probable that the most violent earthquakes are by no means always the most rapidly propagated. The measurements, moreover, do not always apply to the path which the earthquake-waves may have followed. Accurate mathematical determinations are greatly wanted. Quite recently, a result has been obtained with great exactness and judicious consideration of all circumstances, by Julius Schmidt, assistant at the Astronomical Observatory of Bonn, on the Rhine earthquake

of the 29th of July 1846. The velocity of propagation obtained for that earthquake was 1466 English feet in a second. This is a rapidity exceeding that of the wave of sound in the air; but if we consider that the velocity of the sound-wave in water is, according to Colladon and Sturm, 5016 English feet, and in cast-iron tubes, according to Biot, 11,393 feet in a second, the result found for the earthquake-wave will appear to us very small. For the Lisbon earthquake of Nov. 1, 1755, from the coast of Portugal to that of Holstein, Schmidt found (from less accurate data) a velocity more than five times greater than in the case of the Rhine earthquake of the 29th of July 1846. Between Lisbon and Gluckstadt (a distance of 1180 English geographical miles), the rate derived by him is 7955 English feet in a second; which is still 3438 feet less than takes place in cast iron.([251])

Earthquakes, and sudden fiery eruptions of volcanoes, recurring after long intervals of repose, — whether they send forth merely scoriæ, or, like intermitting water-springs, pour forth fluid molten earths in lava streams, — have indeed the same causal connection, or common origin, in the high temperature of the interior of our planet; but one of these phænomena shows itself in most cases quite independently of the other. For example, violent earthquakes, in their linear extension along the chain of the Andes, agitate regions in which there are volcanoes which are not extinct, and are indeed often in a state of activity, yet without causing in them any perceptible excitement. In the great catastrophe of Riobamba, the neighbouring volcano of Tunguragua and the rather more distant one of Cotopaxi remained quite tran-

quil; and inversely, volcanoes have had great and long-continued eruptions without earthquakes having been felt in the country around, either previously or at the same time. The most devastating earthquakes recorded in history, and which have passed through very many thousands of square miles, are precisely those which, so far as could be perceived at the surface of the earth, had no connection with the activity of volcanoes. This class has latterly been termed *plutonic*,—in opposition to properly *volcanic* earthquakes which are mostly limited to lesser areas. This nomenclature, which would require far the greater number of earthquakes to be called plutonic, is not to be approved as respects more general views.

We have everywhere beneath our feet that which may produce earthquake shocks; and the consideration that almost three fourths of the earth's surface are covered by sea, and (omitting a few sporadically scattered islands) without any permanent communication between the interior and the atmosphere (*i.e.* without active volcanoes), sufficiently refutes the erroneous but widely-spread belief, that all earthquakes are to be attributed to the eruption of a distant volcano. Continental earthquakes are indeed often propagated over the bottom of the sea, and the agitation communicated from the coast, causes those formidable sea-waves of which the earthquakes of Lisbon, Callao, and Chili have given such memorable examples. When, on the other hand, the earthquake proceeds from the bottom of the sea, from the dominions of the earth-shaking Poseidon (σεισίχθων, κινησίχθων), and is not accompanied by an upheaval producing an island (as in the ephemeral

existence of the Island Sabrina or Julia), there may be remarked at points where yet the mariner would not feel any shock, an unusual heaving and rolling of the waves. The inhabitants of the Peruvian coast often directed my attention to this phænomenon. In the harbour of Callao, and at the Island of San Lorenzo which is opposite to it, in perfectly calm, windless nights, in this exceedingly tranquil part of the Pacific, I have myself seen suddenly wave rise upon wave to a height of eleven to fourteen feet, continuing for a few hours. Nor can we, in these latitudes, as we might do elsewhere, explain the phænomenon by the supposition of a violent storm having occurred far out at sea.

To begin with agitations of the earth limited to the smallest space, and obviously owing their origin to the activity of a volcano, I will mention first what I observed when seated with my chronometer in my hand at night in the crater of Vesuvius, at the foot of a small cone of eruption; it was after the great earthquake at Naples, on the 26th of July 1805, and after the eruption of lava which followed seventeen days later. I regularly felt the ground of the crater shake every twenty or twenty-five seconds, immediately before each eruption of glowing scoriæ or cinders. Of these, which were thrown to a height of fifty or sixty feet, part fell back into the opening from which they had issued, and part covered the sides of the cone. The regularity of the phænomenon rendered the observation free from danger. The repeated small shocks which I felt were not sensible beyond the crater, *i.e.* at the Atrio del Cavallo, or at the hermitage del Salvatore. The periodicity of the shaking showed that it depended on

a definite degree of tension, which it was necessary that the vapours should reach before they could burst through the molten mass in the interior of the cone of cinders. Just as in the case described, in which no shocks were felt on the sides of the cinder-cone of Vesuvius, so in a quite analogous phænomenon, though on a far grander scale, on the cone of ashes of the volcano of Sangai, which rises south east of the city of Quito to a height of 17,100 English feet, a very distinguished observer, Herr Wisse, having (in December 1849) approached within a thousand feet of the summit and crater, perceived no quaking of the ground,([252]) although 267 explosions (eruptions of scoriæ) were counted in the course of a single hour.

A second, immensely more important, class is the very numerous one which consists of earthquakes usually accompanying or preceding great eruptions, whether of volcanoes which, like our European ones, pour forth streams of lava; or of volcanoes which, like Cotopaxi, Pichincha, and Tunguragua in the Andes, send forth only scoriæ, ashes, and vapours. It is especially in regard to this class that volcanoes may be viewed as safety-valves, or vents, according to the early remark of Strabo on the fissure from which lava flowed, near Lelante, in the island of Eubœa. The earthquakes cease when a considerable eruption has taken place.

The most wide-spread devastations ([253]) are those occasioned by earthquake-waves which traverse partly non-trachytic and non-volcanic countries, and partly trachytic and volcanic ones, as the Cordilleras of South America and Mexico, without exercising any influence on the neighbouring volcanoes. These form the third class or

group of phænomena, and it is that which points most strongly to the existence of a general cause in the thermic constitution of the interior of our planet. To this third group belongs also a case of rare occurrence in which, in countries non-volcanic and rarely visited by earthquakes, the ground trembles uninterruptedly for several months, on a very restricted space, seeming to presage an upheaval, and the formation of an active volcano. This took place in the beginning of the present century in the Piedmontese valleys of Pelis and Clusson, as well as at Pignerol in April and May 1808, and also in the spring of 1829, in Murcia, between Orihuela and the sea-coast, on a space rather less than a (German) square mile. When in the interior of Mexico, on the western slope of the high land of Mechoacan, the cultivated flat of Jorullo was incessantly shaken for ninety days, the volcano rose surrounded by many thousand small cones, about five or seven feet high (los hornitos), and poured forth a brief but powerful stream of lava. On the other hand, in Piedmont and in Spain, the shaking of the earth gradually ceased without any great natural event ensuing.

I have thought it useful to enumerate the wholly different kinds of manifestation of the same volcanic activity (or reaction of the interior of the earth on its exterior), in order to guide the observer, and aid in providing materials which may lead to fruitful results respecting the causal connection of the phænomena. Sometimes the volcanic activity embraces at one time, or at times little distant from each other, so large a portion of the earth, that the shocks which are felt may be attributed to several kindred causes at once. The

years 1796 and 1811 especially offer remarkable examples ([254]) of such a grouping of phænomena.

b. *Thermal Springs.*

(Enlargement of the Picture of Nature in Cosmos, Vol. I. p. 207—211.)

We have described *Earthquakes* as a result of the vital activity of the interior of our planet, manifesting itself in irregularly repeated and often fearfully destructive phænomena. In earthquakes, regarded according to their essentially inherent character, the volcanic power displayed acts dynamically only, or as an energy giving rise to motion; although in some localities, under particular collateral conditions, it may be the means, not indeed of *producing* particular kinds of substances (as do volcanoes proper), but of bringing them to the surface of the earth. In like manner as in earthquakes, water, vapours, petroleum, mixtures of gases, or pasty masses (mud, and "moya") are occasionally, and during periods of brief duration, brought to the surface and emitted through suddenly opened fissures;—so fluids, both liquid and gaseous, flow permanently from the bosom of the earth through the existing generally distributed network of intercommunicating fissures. We thus place by the side of the transitory and tumultuous phænomena of emission, that vast and tranquil system of springs, wells, and fountains, by which organic life is beneficently nourished and refreshed, and by means of which, for thousands of years, the moisture withdrawn from the atmosphere by the fall of rain, is restored to the service of the organic creation. Analogous phænomena in the great economy of nature are

mutually illustrative of each other, and some allusion to such connecting links as can be recognised between them should not be omitted where generalisation of view is desired.

The division of springs into warm and cold, which is in such general use, and in ordinary parlance appears so natural, will be seen to rest only on very uncertain foundations, if it is wished to reduce it to definite numerical expression. If the temperature of springs is to be compared with that of the human body (the internal heat of which Brechet and Becquerel found with thermo-electric apparatus to be from 98·1° to 98·6° Fahr.) the degree of the thermometer scale at which a liquid when placed in contact with parts of the body would be called cold, warm, or hot, will differ considerably according to individual feelings. No absolute degree of temperature can be determined on, as that above or below which a spring shall always be termed warm or cold. The proposal to call, in each climatic zone, a spring, whose mean annual temperature does not exceed the mean annual temperature of the air in the same zone, a cold spring, offers, at least, scientific accuracy in the comparison of definite numbers. It has also the advantage of leading to considerations respecting the different *origin* of springs; since the agreement with the mean annual atmospheric temperature is to be looked for in "invariable" springs directly, and in "variable" ones (as Wahlenberg and the elder Erman have shown) in the mean of their summer and winter temperatures. But according to this criterion, in one zone a spring may be termed "warm," whose temperature is scarcely a seventh or an eighth part of that of another which being situated in the equatorial regions

is termed "cold." I take the difference between the mean temperatures of St. Petersburg (38·1° Fahr.), and the banks of the Orinoco. The purest spring waters that I ever drank while I remained in the district of the Cataracts of Atures and Maypures, ([255]) or in the forests of Atabapo, had a temperature of upwards of 26° Cent. or 78·8° Fahr. And the temperature of the great rivers of tropical South America corresponds to that of these which would in such case be technically called "cold" springs! ([256])

The flowing forth of springs, occasioned by various causes of pressure, and by the interconnection of fissures containing water, is a phænomenon so general over the earth's surface, that at some points it takes place in the highest uplifted mountain strata, and at others at the bottom of the sea. In the first quarter of the present century, Leopold von Buch, Wahlenberg, and I collected numerous results respecting the temperature of springs and the distribution of heat in the interior of the earth in both hemispheres, from the 12th degree of south to the 71st degree of north latitude. ([257]) The springs which have an "invariable" temperature were carefully distinguished from those which vary with the seasons; and Von Buch remarked the powerful influence of the distribution of the fall of rain in the course of the year, or the relative frequency and abundance of winter- and summer-rains, on the temperature of the "variable springs," which are, generally speaking, the most numerous and widely diffused class of springs. This influence has recently been placed in a clearer light, both in a geographical and hypsometrical view (or according to latitude and to elevation), by de Gasparin,

Schouw, and Thurmann. [258] Wahlenberg maintained that in *very high latitudes* the mean temperature of variable springs is somewhat higher than the mean temperature of the air; he looked for the cause of this, not in the dryness of very cold air and the consequent less abundance of winter rain, but in the protecting covering of snow diminishing the radiation of heat from the ground. In those parts of the great plains of Northern Asia in which a perpetual "stratum of ice," or at least frozen soil with interspersed pieces of ice, is found at a depth of a few feet, [259] the temperature of springs cannot, without great caution, be used in making out Kupffer's important theory of isogeothermal lines. In such situations there takes place a twofold radiation of heat from the upper stratum of the earth; upwards towards the atmosphere, and downwards towards the ice stratum. An extensive series of valuable observations collected by my friend and companion Gustav Rose, in the Siberian Expedition, in the heat of summer (often in wells still surrounded with ice), between the Irtysch, the Obi, and the Caspian Sea, showed a great complication of local disturbances. Similarly perturbing influences, arising from entirely different causes, show themselves in results obtained within the tropics, from mountain springs issuing forth on vast table-lands eight or ten thousand feet above the sea (Micuipampa, Quito, Bogota), or on slender isolated summits many thousand feet still higher; these comprehend a more extensive part of the earth's surface, and are useful in leading to the consideration of analogous thermic relations in mountainous countries in the temperate zone.

In this important subject it is first of all necessary to

separate actual observations from the theoretical conclusions which have been based upon them. The object we aim at, enounced in its greatest generality, is a threefold one:—the distribution of heat, in the accessible part of the earth's crust, in the aqueous covering (the ocean), and in the atmosphere. In the liquid and gaseous coverings of the globe, an opposite variation of temperature takes place in the vertical direction. In the solid parts of the globe, the temperature increases with increasing depth; the variation being here the same in direction (though the ratio is very different) as in the atmospheric ocean, in which elevated plateaus and variously shaped mountain summits represent shoals and submarine rocks. We are acquainted by direct experiment with the distribution of heat in the atmosphere, geographically or in different latitudes and longitudes, and hypsometrically or at different amounts of vertical elevation above the level of the sea. This knowledge is, however, almost wholly confined to the near vicinity of the solid or liquid surface. Scientific and systematically arranged investigations, by means of aërostatic explorations of the aërial ocean beyond the immediate proximity of the disturbing influences of the earth, are still so much too few in number, that they have for that reason been little capable of affording the requisite numerical data for *mean* conditions. In regard to the decrease of temperature in the depths of the ocean, observations are not wanting; but currents bringing water from different latitudes and depths, and of different densities, interpose almost greater obstacles to the attainment of general results than do the currents of the atmosphere. The thermic conditions of the two

coverings of our planet, which will be treated of more particularly in the sequel, are here referred to in passing, in order that the influence of the vertical distribution of temperature in the solid crust of the earth, (the system of "geoisothermals,") may not be looked at in too isolated a manner, but that it may be regarded rather as a portion of the all-pervading movement of heat, — a true "cosmical activity."

Instructive as are in many respects observations on the unequal decrease of temperature with increasing elevation of their point of issue of such springs as do not vary with the seasons, yet the local law of such decrease ought not to be regarded, as it too often is, as a general "geothermic" law. If we were assured that the springs came from unmixed waters, resting on very extensive horizontal strata, we might indeed believe them to have gradually acquired the temperature of the solid materials in the vicinity; but the great network of fissures by which the upheaved masses are intersected must render this only a rare case. Colder waters from higher levels mix with the lower ones. Our mining operations, small as is the depth to which they penetrate, are very instructive in this respect; but we shall not arrive directly at the knowledge of the geothermal lines until observations are obtained at very various elevations above the level of the sea by Boussingault's method, *i.e.* by sinking the thermometers into the earth below the depth to which the influence of the variations of the adjacent atmosphere extends.([260]) From the 45th parallel of latitude to the parts of the tropics nearest to the equator, the depth at which the "invariable" stratum begins decreases from 64 feet

to about 2 feet. It is therefore only within the tropics, or at no great distance beyond them, that this method of arriving at the knowledge of the mean temperature of the ground is easily practicable. The valuable resource offered by Artesian wells (which, with absolute depths of from 750 to 2340 feet in round numbers, have shown an increase of temperature of 1° Fahr. for a mean descent of 56 feet,) has as yet only been available to physical inquirers in districts not more than 1600 feet above the level of the sea. ([261]) I have visited excavations made in search of silver ores in the Andes 6° 45′ south of the equator, at an elevation of 13,200 feet, and I there found the temperature of the waters oozing out of the fissures in the limestone rock 52·3° Fahr.([262]) The waters which on the ridge of the Andes, at the Paso del Assuay, were warmed for the baths of the Inca Tupac Yupanqui, came probably from the springs of the Ladera de Cadlud; where, by barometric measurement, I found the elevation of the path (near which ran also the ancient skilfully constructed Peruvian road,) 15,525 feet above the sea, or nearly equal to the height of Mont Blanc.([263]) These are the highest points at which I was ever able to observe spring water in South America. In Europe, in the Eastern Alps, the brothers Schlagintweit, at the height of 9440 feet, found the temperature of the water in the gallery of a gold mine (the "Goldzeche"), and of small springs near the mouth of the gallery, only 33·4° Fahr.,([264]) at a distance from either snow or glacier ice. The limits of elevation at which springs are met with differ with differences of latitude and of the height of the line of perpetual snow; and also with the different pro-

portions which the elevations of the loftiest peaks bear to those of the general crests of the mountains and of the table-lands.

If the semi-diameter of our planet were increased by the height of the Himalayan summit of Kinchinjunga, 28·175 feet, this addition of only about $\frac{1}{800}$ of the earth's radius would scarcely make any difference (according to Fourier's analytic theory) in the temperature of the surface as cooled by radiation; the thermal condition of the upper portion of the crust of the earth would be almost exactly the same as it now is. But where particular parts of the surface rise into the atmosphere, whether in mountain chains, or in isolated summits, there takes place in the interior of the upheaved strata a decrease of warmth from below upwards, which decrease is modified by contact with strata of air of unequal temperatures; by the different capacity for heat and the different heat-conducting power of different kinds of rock; by the exposure to the sun's rays of the bare or forest-covered summits and declivities; and by the greater or less radiation from the mountain, according to the particular form of its relief, whether forming a wide mass, or one or more narrow cones or pyramids. The particular height of the region of clouds; the extent of icy or snowy covering (varying according to the different heights of the snow limit); and the frequency of the currents of colder air, which at particular parts of the twenty-four hours roll down the steep declivities; all modify the effects of terrestrial radiation. As the soaring jagged peaks become colder, there arises in the interior a faint current of heat from below upwards, tending towards, but never attaining,

the production of a state of equilibrium. The recognition of so many agencies affecting the vertical distribution of heat, leads to well-founded conjectures respecting the connection of complicated local phænomena, but not to the derivation of any direct numerical determinations. In mountain springs, (and the higher ones, being important to the Chamois hunters, are carefully sought out,) a doubt often subsists as to their being mixed, either with waters which sinking down from above bring a colder temperature, or with waters rising from below and bringing with them the higher temperature of more deeply seated strata. From nineteen springs observed by Wahlenberg, Kämtz draws the conclusion that in the Alps we require to ascend between 960 and 1020 feet, to see the temperature of springs diminish 1·8° Fahr. (average, 550 feet to 1° Fahr.) More numerous and more carefully selected observations by Hermann and Adolph Schlagintweit, in the eastern Carinthian, and the western Swiss Alps round Monte Rosa, give a more rapid decrease of temperature, viz. 1·8° Fahr. to only 767 feet (426 feet to 1° Fahr.). According to the great work of these excellent observers, (265) "the rate of decrease of the temperature of the springs with increasing elevation is in every case somewhat slower than that of the mean annual temperature of the atmosphere, which in the Alps gives 319 English feet for 1° Fahr. The springs there are, generally speaking, warmer than the mean temperature of the air at the same level; and this difference between the temperature of the air and the springs increases with the elevation. The temperature of the ground at equal heights is not the same throughout

the Alps; for, apart from the influence of geographical latitude, the elevation of the isothermal planes, connecting the points at which the springs have the same mean temperature, increases with the increasing mean elevation of the surrounding country: all in accordance with the laws of the distribution of heat in a solid body of varying thickness, to which the relief (or mass elevation) of the Alps may be compared."

In the Andes, and precisely in that volcanic portion of the chain which presents the greatest elevations, the sinking of thermometers in the ground may in some cases, under the influence of particular circumstances, give rise to delusive results. In pursuance of a previously formed opinion, that the entire absence of snow on the dark ridges of black rock, seen from afar intersecting the snowy region, may not always be exclusively due to the configuration and steepness of their sides, but may also be in part attributable to other causes,—I plunged the bulb of a thermometer only three or four inches into the sand, which filled the cleft in such a ridge on the Chimborazo, at an elevation of 18,288 feet, or 2550 feet higher than the summit of Mont Blanc. The thermometer showed persistently 42°·4 Fahr., while the external air was only 36°·9. The result of this observation is of some importance, because 2560 feet lower down, at the lower limit of perpetual snow on the volcanoes of Quito, the mean temperature of the air, inferred from a large number of observations collected by Boussingault and myself, is under 35°. The temperature of 42°·4 must, therefore, have been due to the subterranean warmth of the dolerite mountain: I do not mean to say to the temperature of the entire

mass, but to that of currents of air rising from lower depths. There is, moreover, at the foot of the Chimborazo, at an elevation of 9500 feet, not far from the village of Calpi, a small crater of eruption called Yana-Urcu, which, in the middle of the 15th century, appears to have been in a state of activity, as is also indicated by its black scoriaceous rock (augitic porphyry.) ([266])

The aridity of the plain out of which the Chimborazo rises, and the existence of the subterranean brook of which the rushing sound is heard under the above-named volcanic hill Yana-Urcu, led both Boussingault and myself, ([267]) at very different times, to consider that the waters proceeding from the daily melting of the enormous masses of snow at their lower limit, sink down into deep clefts and hollows below the upheaved volcanoes. These waters produce continual refrigeration in the strata through which they sink. But for this agency the entire dolerite and trachyte mountains, even at times when there is no indication of any proximate eruption, would have a still higher internal temperature imparted to them by the ever-acting primeval volcanic source of heat, which, perhaps, is not at an equal depth in all zones of the earth. Thus, in the conflict between heating and cooling causes, the existence of a perpetual flow of heat both upwards and downwards may be most particularly assumed where the solid parts of the earth's surface rise high into the atmosphere.

Mountains and high summits, however, regarded relatively to the area which they occupy, are but a very small phænomenon in the relief-form (or vertical configuration of the dry land); and, moreover, almost two

thirds of the whole surface of the earth (according to the present state of geographical discovery in the polar regions of either hemisphere, the ratio of sea and land may be taken as 8 : 3) are sea-bottom. This is in immediate contact with strata of water, slightly salt, and which, following the order of superposition corresponding to their temperature of maximum density (39°·1 Fahr.), are of an icy coldness. Exact observations by Lenz and du Petit-Thouars have shown that in the midst of the tropics, where the surface of the ocean has a temperature of about 80°, water of $36\frac{1}{2}$° Fahr. may be drawn up from depths of seven or eight hundred fathoms; a phænomenon which manifests the existence of submarine currents from the polar regions. The consequences of this sub-oceanic constant cooling process of by far the larger portion of the earth's crust, deserve a greater measure of attention than they have hitherto received. Rocks and islands of small circumference rising like cones from the bottom of the sea above the surface of the waters, and narrow isthmuses, such as Panama and Darien, washed by wide oceans, must present a different internal distribution of heat, to that existing in masses of similar form and density in the interior of continents. In a lofty mountain-island, the submarine portion of its vertical height is in contact with a fluid of which the temperature increases from below upwards; while, as the rocky strata emerge from the sea, they come in contact, under the influence both of the sun's direct rays and of free outward radiation, with a gaseous fluid in which the temperature decreases with increasing height. Similar thermal relations, of opposite decrease and increase in the vertical line,

are found in the narrow tract (Ust-Urt) intermediate between two great inland seas, the Caspian and the Aral. In order, at some future time, to elucidate fully phænomena so complicated, it will be needful to employ exclusively methods which lead directly to the knowledge of the internal temperature, such as deep borings, and not to trust merely to observations of the temperature of springs, or of the atmosphere in caves; for these give results as insecure as does the temperature of the atmosphere in the galleries and chambers of mines.

In comparing a low flat land with mountain-ridges rising abruptly many thousand feet, or with high table-lands, the law of increasing and decreasing temperature does not depend simply on the relative heights of the points compared. If we should compute, according to a determinate scale, the variation of temperature for a given number of feet taken in proceeding upwards from the plain to the summit, and in a line downwards from the summit to a stratum in the interior of the mass of the mountain on a level with the surface of the plain, we should find, in the one case, the summit much too cold, and in the other, the interior stratum much too warm. The distribution of heat in a mountain elevation (an undulation of the earth's surface) is dependent, as has been already remarked, on the form and mass of the mountain,—the conducting power of the rocks of which it consists,—the heat received from the sun's rays on the one hand and lost on the other by radiation, both in measure varying with the clear or clouded character of the atmosphere,—and on the contact and varying play of ascending and descending currents of air: granting these suppositions, we might reasonably expect

that, with very moderate differences of elevation, such as four or five thousand feet for example, mountain-springs would frequently be found, whose temperature should be from 70° to 90° Fahr. above the mean temperature of the place; and lastly, what might we not expect would be the case at the foot of mountains in the torrid zone, which, at a height of nearly 15,000 feet, are still free from perpetual snow, and which often show no volcanic rocks, but only gneiss and mica-slate? ([268]) The great mathematician Fourier, the year before his death, (at my solicitation, and stimulated by the consideration of the topography of the eruption of Jorullo in a plain where, for many hundred square leagues around, no traces of unusual terrestrial heat had been discovered,) engaged in theoretical investigations into the question of the manner in which, in cases of upheavals and altered configuration of the surface, the isothermal planes adjust themselves afresh, in accordance with the new form of the ground. The lateral radiation of strata, which are situated at the same level but unequally covered, has greater influence in this matter, than has the inclination of the planes of separation of the rock where stratification is discernible.

I have already remarked elsewhere, ([269]) how the hot springs in the vicinity of ancient Carthage, probably the thermal waters of Pertusa (aquæ calidæ of Hammam-el-Enf), led the martyr, Bishop Patricius, to a correct view as to the cause of the higher or lower temperature of the gushing fountains. When the pro-consul Julius sought mockingly to perplex the accused bishop by the question, "Quo auctore fervens hæc aqua tantum ebulliat?" Patricius, in reply, unfolded his theory of central

heat, "which occasions the fiery eruptions of Etna and Vesuvius," and "renders springs so much the warmer as their origin is deeper." He considered the Pyriphlegethon of Plato to be the hell of sinners; and further, as if he would have recalled one of the cold hells of the Buddhists, supposed, somewhat unscientifically, for the "nunquam finiendum supplicium impiorum," notwithstanding the depth, an "aqua gelidissima concrescens in glaciem."

Among hot springs, those which attain a temperature of 194° Fahr. (approaching the boiling point of water, 212°) are much more rare than, from inexact observations, is commonly believed, and least of all are they to be looked for in the neighbourhood of still active volcanoes. In my American journey, I was able to examine two of the most important of such springs, both within the tropics. In Mexico, not far from the rich silver mines of Guanaxuato, in 21° north latitude, at an elevation of fully 6400 feet above the level of the sea, ([270]) the Aguas de Comangillas gush forth from a mountain of basalt and basaltic breccia. I found their temperature, in September 1803, 205°·5 Fahr. This basaltic mass has been broken through by a dyke of columnar porphyry, which itself rests on a white quartzose syenite. Higher up, but not far from this almost boiling spring, at los Joares, north of Santa Rosa de la Sierra, snow falls from December to April at an elevation of only 8700 feet; and throughout the year the natives prepare ice, by means of radiation, in artificial basins. In the route from Nueva Valencia in the Valles de Aragua to the harbour of Portocabello (in about 10¼° north latitude), on the northern declivity of the Venezuelan

coast chain, I saw the aguas calientes de las Trincheras gush forth from a stratified granite which does not pass into gneiss. I found the temperature of this spring, in February 1800, 194°·5, ([271]) while the Baños de Mariara in the Valles de Aragua, which are in gneiss rock, showed 138°·7. Three and twenty years later, again in the month of February, Boussingault and Rivero ([272]) found at the Mariara waters 147°·2, and at the Trincheras de Portocabello, but little above the Caribbean Sea, in one basin 198°, and in the other 206°·6. It would appear, therefore, that in the short interval of little more than twenty years, an unequal change of temperature had occurred in these springs, the increase in the temperature of the Mariara waters being 8°·5, and in that of the Trincheras 12°·1. Boussingault rightly called attention to the fact that the dreadful earthquake, which overthrew the town of Caracas on the 26th of March, 1812, took place in this very interval. It is true that at the surface of the earth the commotion was less in the neighbourhood of the lake of Tacarigua (in Nueva Valencia); but in the interior of the earth, where elastic vapours act in clefts and fissures, may not a movement propagating itself so widely, and with so much violence, easily modify the network of fissures, and open deeper channels for the access of heat? The hot waters of the Trincheras rising out of a granite formation are almost pure, containing only traces of silica, sulphuretted hydrogen and nitrogen. After forming several very picturesque cascades, bordered by luxuriant vegetation, they become a river, the Rio de Aguas calientes, which as it approaches the sea is full of large crocodiles, the still high, though already

greatly diminished, temperature suiting those creatures extremely well. In the extreme north of India (lat. 30° 52′), the very hot spring of Jumnotri rises out of granite, at an elevation of 10,850 feet above the sea-level, with a temperature of 194° Fahr., being nearly the boiling point of water under the atmospheric pressure corresponding to that altitude. ([273])

Among intermitting hot springs, the boiling fountains of Iceland, and among these especially the Great Geysir and the Strokr, have deservedly acquired the most celebrity. In both, according to the excellent recent researches of Bunsen, Sartorius von Waltershausen, and Descloiseaux, the temperature in the jets of water decreases from below upward with remarkable rapidity. The Geysir has a truncated cone, about 26 or 30 feet high, formed of horizontal strata of silicious concretion. In this cone there is a shallow depression about 55 or 56 feet broad, in the middle of which a funnel about 18 feet in diameter descends to a depth of 75 feet. The temperature of the water, which always fills the basin, is nearly 180° Fahr. At very regular intervals of about 80 or 90 minutes, subterranean thunder announces the beginning of the eruption. Columns of water nine or ten feet diameter, of which about three large ones follow each other in immediate succession, shoot upwards to the height of more than a hundred, sometimes to even nearly a hundred and fifty feet. The temperature of the water which rises in the funnel has been measured at a depth of 72½ feet, and found, a short time before the eruption, 260°·6 ; during the eruption, 255°·6 ; and immediately after it 251°·6 At the surface of the basin it was only from 183° to 185°. The Strokr, which is also

situated at the foot of the Byarnefell, has less water than the Great Geysir. The siliceous margin of its basin is only a few inches high and wide. Its eruptions are more frequent than those of the Geysir, but do not announce themselves by subterranean noise. In the Strokr the temperature at the time of eruption is from 235°·4 to 239° at a depth of 42½ feet, and almost 212° at the surface. The eruptions of the intermitting boiling fountains, and the small variations in the type of their phænomena, are quite independent of the eruptions of Hecla, and were in no ways interrupted by those which took place in 1845 and 1846.([274]) Bunsen, with his peculiar sagacity both in observation and discussion, has refuted the formerly received hypotheses respecting the periodicity of the Geysir eruptions (subterranean hollows filled as steam-boilers alternately with vapours and with water). According to his view, the eruptions take place because a part of a column of water, which at some lower depth has gained a high degree of temperature under great pressure by accumulated vapours, is pushed upwards, and thus comes under a pressure in which a portion of the water is converted into steam. Thus, "the Geysirs are natural collectors of steam-power."

Among hot springs, some few are almost absolutely pure, others contain solutions of as many as from 8 to 12 solid or gaseous substances. To the first class belong the Luxueil, Pfeffers, and Gastein waters; of which the nature of the efficacy appears so perplexing on account of their purity. ([275]) As all springs are principally fed by meteoric water, (water which has fallen in rain, hail, or snow,) they contain nitrogen; as Boussingault has

shown to be the case in the very pure spring which flows from granite rock in the Trincheras de Portocabello, ([276]) and Bunsen ([277]) in the Cornelius spring at Aix-la-Chapelle, and in the Geysirs of Iceland. The organic matter which is held in solution in several springs is also nitrogenous, and even sometimes bituminous. Formerly, before it was known by Gay-Lussac's and my own experiments, that rain and snow-water contain (the first 10 and the last at least 8 per cent.) more oxygen than the atmosphere, it was thought very surprising that it should be possible to obtain from the springs of Nocera, in the Apennines, mixture of gases in which there was an abundance of oxygen. The analyses of Gay-Lussac, made while we resided near this mountain-spring, showed that it contained no more than the amount of oxygen which it could derive from rain or snow. ([278]) If we are disposed to wonder at the silicious deposits which in the Geysirs appear more like building materials, out of which nature has put together forms resembling artificial constructions, we may be reminded that silica is also contained in many cold springs which have in them only a very small portion of carbonic acid.

Saline springs and exhalations of carbonic-acid gas, which were long ascribed to beds of coal and lignite, appear to be due wholly to processes of deep-seated volcanic activity; an activity, not manifesting itself solely where volcanic rocks testify the existence of ancient local igneous eruptions, but everywhere diffused. Carbonic-acid exhalations are, indeed, the phænomena which in extinct volcanoes longest survive plutonic catastrophes: they succeed to the stage of solfatara activity; but at the same time waters of the most different temperatures

issue, strongly impregnated with carbonic acid, alike from granite, gneiss, and the older and newer sedimentary rocks. Springs containing acids become impregnated with carbonates, particularly with carbonate of soda, wherever waters having carbonic acid act on rocks which contain alkaline silicates. ([279])

In the north of Germany, at many of the carbonic-acid springs of water and gas, the still subsisting dislocation of the strata and the character of the valleys in which the springs break forth, for the most part "annular valleys" (as at Pyrmont, Driburg, &c.), are particularly striking. Friedrich Hoffmann and Buckland almost simultaneously gave to such depressions the very characteristic name of "valleys of elevation" (Erhebungs-Thäler).

In the springs termed sulphur-waters, the sulphur is by no means found always in the same combinations. In many which contain no carbonate of soda, sulphuretted hydrogen is probably held in solution; in others, for example in the sulphur-waters of Aix-la-Chapelle (in the Kaiser, Cornelius, Rose, and Quirinus springs), the gases obtained by boiling with the air excluded, do not contain, according to exact experiments by Bunsen and Liebig, any sulphuretted hydrogen; and even in the bubbles of gas which rise spontaneously from the springs themselves, it is only in the Kaiser spring that 0·31 per cent. of sulphuretted hydrogen is obtained.([280])

A thermal spring, giving birth to an entire river of water impregnated with sulphurous acid, the Vinegar River (Rio Vinagre), called by the natives Pusambio, is a remarkable phænomenon, which I was the first to make known. The Rio Vinagre rises, at a height of about 10,600 feet, on the north-western declivity of the

volcano of Purace, at the foot of which the town of Popayan stands. It forms three picturesque cascades,(281) of one of which, which falls over a precipice more than 300 feet high, I have given a drawing. From the point where this small stream falls into the Cauca, to the mouths of the Pindamon and Palace 10 or 12 miles lower down, no fish are found in that large river, much to the annoyance of the inhabitants of Popayan, who are strict observers of ecclesiastical fasts. The waters of the Pusambio contain, according to Boussingault's later-made analysis, a large quantity of hydrosulphuric acid and carbonic acid gases as well as some sulphate of soda. Near the source Boussingault found the temperature 163°. The upper portion of the course of the Pusambio is subterranean. In the Paramo de Ruiz, on the side of the volcano of the same name, at the sources of the Rio Guali, at an elevation of 12,150 feet, Degenhardt (a geologist from Clausthal in the Hartz, whose early death is a loss to geological science,) discovered in 1846 a hot spring in the waters of which Boussingault found three times as much sulphuric acid as in the Rio Vinagre.

The persistent identity in temperature and chemical composition of much the greater number of thermal springs as far back as can be traced by secure observations, is a more remarkable fact than the variations which have been made out in a few cases. (282) Thermal springs, whose waters during their long and intricate course take up from the rocks with which they come in contact a variety of ingredients, which they often conduct to parts where the strata are wholly wanting in such components, exert also another and entirely different kind of action, —an action at once metamorphic

and formative. In this point of view they are of great geological importance. Senarmont has shown with admirable sagacity the manner in which it is highly probable that many veins, ancient channels of thermal waters, have been filled from below upwards by deposits of the elements which had been held in solution. By changes of pressure and temperature, by internal electro-chemical processes, and by the specific attraction of the side walls, lamellar divisions have taken place and concretions have been formed. Drusic cavities and porous amygdaloids seem to have been formed partly in this manner. When the deposit in veins has taken place in parallel zones, these zones correspond to each other as respects their constitution, for the most part symmetrically from the sides.

Senarmont's chemical ingenuity succeeded in obtaining artificially a considerable number of minerals by quite analogous, synthetic processes. ([283]) I hope that a scientifically gifted observer, nearly connected with myself, will shortly publish a new and important investigation respecting the temperatures of springs, in which, by induction from a long series of observations, he will treat the intricate phænomena of disturbing effects with great generality. Eduard Hallmann, in the thermometric measurements obtained by him during the years from 1845 to 1853 in Germany (on the Rhine), and in Italy (in the country round Rome, in the Alban hills, and in the Apennines), distinguished between, 1st, pure meteorological springs, whose mean temperature is not raised by the internal temperature of the earth; — 2nd, meteorolo-geological springs; which being independent of the distribution of rain, and warmer than the atmo-

sphere, undergo only such changes of temperature as are imparted to them by the ground through which they issue forth;—3rd, abnormally cold springs, in which the low temperature is brought down from great heights. ([284]) The greater the advance which has been made of late years, by the happy application of chemistry to geology, towards a knowledge of the mode of formation, and of the metamorphic alteration, of rocks, the greater has been the importance attaching to the consideration of those spring waters which circulate through the crust of the earth, charged with different salts and gases, and which when they break forth at the surface as thermal waters have already completed the greater part of their formative, metamorphic, or destructive functions.

c. *Springs of Vapour and Gas, Salses, Mud-volcanoes, Naphtha-flames.*

(Enlargement of the Picture of Nature in Cosmos, Vol. I. pp. 211—213.)

In the general picture of nature in the first volume of this work I have shown, by examples which have been well made out, although they have not been sufficiently attended to, that "Salses" in the different stages through which they pass, from eruptions accompanied by flames to mud emitted quietly, form, as it were, an intermediate link between hot springs and volcanoes proper; which latter throw up molten earths, in the shape of disconnected scoriæ, or, as newly formed and often variously superposed rocks. Like all transitions and inter-

mediate links in inorganic and organic nature, salses and mud-volcanoes are well-deserving of a serious attention, which the older geologists, for want of special knowledge of the facts, were not so well able to bestow on them.

Salses and naphtha-springs are found, in some cases, in small detached groups; as the Macalubi in Sicily, near Girgenti (referred to so early as by Solinus), those near Pietra Mala, Barigazzo and at the Monte Zibio, not far from Sassuolo in the north of Italy, and at Turbaco in South America;— and in other cases (which are the more important and instructive) arranged as it were in long narrow lines. The mud-volcanoes of Taman on the north-west of the chain of the Caucasus, and the naphtha-springs and burning naphtha of Baku and of the Caspian peninsula of Apscheron on the south-east, have long been known ([285]) as the extreme links belonging to that great mountain-chain; but the magnitude and connection of these phænomena were first shown by Abich, who is profoundly acquainted with that portion of western Asia. According to his views, the Caucasian mud-volcanoes and founts of burning naphtha are recognisably connected with certain lines, which are in unmistakable relation to the "axes of elevation" and "directions of dislocation" of the strata. The larger portion of the south-eastern part of the Caucasus is occupied by genetically connected mud-volcanoes, naphtha exhalations, and saline springs in a triangle with two equal sides, having for its base the shore of the Caspian from Balachani (north of Baku) to one of the mouths of the Kur (Araxes) near the hot springs of Sallian, and for its apex Schagdagh in the high valley of Kinalughi.

Not far from the village of Kinalughi, at an elevation of nearly 8350 feet above the Caspian and at the junction of a dolomite and a slate formation, there break forth "the perpetual fires of Schagdagh," which are never extinguished by the weather. The axis of this triangle corresponds to the direction which appears to be constantly followed by the earthquakes, which are so often experienced in Schamacha, on the banks of the Pyrsagat. If this north-western direction is prolonged, it encounters the hot sulphurous springs of Akti, and then becomes the line of the principal crest of the Caucasus, where it rises to the Kasbegh and bounds the western part of Daghestan. The salses of the low country, often regularly arranged in line, become gradually more frequent towards the shore of the Caspian between Sallian, the mouth of the Pyrsagat (near the island of Swinoi), and the peninsula of Apscheron. They show traces of former repeated eruptions of mud, and bear on their summits small cones, quite similar in shape to the hornitos of Jorullo in Mexico, from which there exhales an inflammable gas, which indeed often ignites spontaneously. Considerable outbreaks of flames were particularly frequent between 1844 and 1849 on the Oudplidagh, Nahalath, and Turandagh. Close by the mouth of the Pyrsagat, at the mud-volcano of Toprachali, there are found (as proofs of a greatly increased intensity of subterranean heat) "black pieces of marl, which at first sight might be mistaken for dense basalt and exceedingly fine-grained dolerite." At other parts of the peninsula of Apscheron, Lenz found fragments which looked like erupted scoriæ, and at the time of the great burst of flames at Baklichli on the 7th of February 1839, small hollow balls, like what are called

ashes in regular volcanoes, were carried by the wind to a considerable distance.(286)

At the north-western extreme, towards the Cimmerian Bosphorus, are the mud-volcanoes of the Taman peninsula, which group themselves with those of Aklanisowka and Jenikale near Kertch. At one of the salses of Taman there was an eruption of mud and gas on the 27th of February 1793, in which, after much subterranean noise, a column of flame several hundred feet high, rose into the air half-veiled in black smoke. (May not the supposed smoke have been a dense cloud of steam?) It is a remarkable circumstance, and a very instructive one in regard to the nature of the volcancitos of Turbaco, that the gas tested at Taman in 1811, by Friedrich Parrot and Engelhardt, was not inflammable; whereas at the same place, 23 years later, gas received by Göbel in a glass tube burnt, out of the tube, with a bluish flame, like the exhalations from all the salses in the south-eastern part of the Caucasus; but when subjected to precise analysis was found to contain out of 100 parts 92·8 of carburetted hydrogen gas and 5 parts of carbonic oxide gas. (287)

A phænomenon assuredly allied in respect to origin to those of which we are treating, although differing in the substances produced, is that of the eruptions of hot boracic vapours in the Maremma of Tuscany, known under the names of "lagoni," "fumerole," "soffioni," and also "volcani," at Possara, Castel Novo and Monte Cerboli. The vapours have average temperatures varying from 204°·8 to 212°, and at a few points amounting even to 347°. They rise in some cases directly from clefts in the rocks, and in others in pits, in which they throw up small cones formed of liquid mud. They are

seen to rise in whitish whirls of vapour which disperse themselves in the air. The boracic acids, which these aqueous vapours bring up with them from the bosom of the earth, cannot be secured when the vapours of the soffioni are collected in vessels placed above the orifices; for they are so volatile that they escape into the atmosphere. The acid is only successfully obtained in the skilfully arranged establishments belonging to Count Larderel, where the orifices of the soffioni are covered by artificially formed reservoirs of water, which absorb the vapours. ([288]) According to Payen's excellent analysis, the gaseous exhalations contain 0·57 carbonic acid, 0·35 nitrogen, only 0·07 oxygen, and 0·001 sulphuric acid. Where the boracic vapours penetrate the fissures of the rock they deposit sulphur. According to Sir Roderick Murchison, the rock is partly cretaceous, and partly an eocene formation containing nummulites; a "macigno," broken through by upheaved serpentine, which shows itself at the surface in the vicinity at Monte Rotondo.([289]) May we not suppose, it is asked by Bischof, that here, and in the crater of Vulcano, hot steam (aqueous vapour) acts at a great depth on minerals containing boracic acid, or on rocks containing datholite, arinite, and tourmaline, and decomposes them? ([290])

The system of soffioni in Iceland exceeds, both in variety and magnitude, anything with which we are acquainted on the continent. In the Fumarole-Field of Krisuvek and Reykialidh true fountains of mud break forth out of greyish blue clay from small basins with crater-shaped margins. ([291]) Here also definite directions can be pointed out, along which fissures marked by phænomena of this class can be traced. ([292])

There is no part of the earth's surface where hot springs, salses, and eruptions of gas are found, for which we now possess such excellent and detailed chemical examinations as those for Iceland, which we owe to the sagacity and persevering labours of Bunsen. Nowhere, so far as we know, are such varied actions of chemical decomposition, formation, and transformation to be observed over so great a tract of country, and probably in such near proximity to the surface.

Passing from Iceland to the American continent, we find in the state of New York, in the district of Fredonia, not far from Lake Erie, in a basin of strata of Devonian sandstone, an immense number of springs of inflammable gas, (springs of carburetted hydrogen), breaking forth from fissures, and sometimes used for gas-lights; other springs of combustible gas, as at Rushville, take the shape of mud-cones; others, as in the valley of the Ohio, in Virginia, and at the Kentucky river, contain at the same time common salt, and in such case are connected with weak naphtha-springs. Passing to the south of the Caribbean Sea, on the north coast of South America, ten miles S.S.E. of the port of Cartagena de Indias, near the pleasant village of Turbaco, a remarkable group of salses, or mud-volcanoes, presents phænomena which I was the first to describe. At this place, where a glorious view of the colossal snow-covered mountains (Sierras Nevadas) of Santa Marta is enjoyed, there rise on a desert space, in the midst of the primeval forest, 18 or 20 "volcancitos." The larger of these cones of dark grey are from 19 to 23½ feet high, and fully 85 feet in diameter at their base. At the top of each cone there is a circular

opening of from $21\frac{1}{2}$ to 30 inches diameter, surrounded by a little mud wall. The gas rises with great vehemence, as at Taman, in bubbles, each of which, according to my measurements made in graduated glass vessels, contains from 10 to 12 (French) cubic inches. The upper part of the funnel is filled with water resting on a thick mud covering. Adjacent cones do not have simultaneous eruptions, but in each single cone there may be remarked a certain degree of regularity in the times of eruption. Bonpland and I counted pretty regularly five eruptions every two minutes. When one stoops over the little crater opening, one can perceive, generally about twenty seconds before each eruption, a hollow noise in the interior of the earth deep below the base of the cone. In the gas which rose, and which was on two occasions collected with great care, a lighted very thin wax taper was instantly extinguished, as was also a burning splinter of Bombax Ceiba. The gas could not be made to ignite. It did not render lime-water turbid; no absorption took place. When tested by nitric oxide gas for oxygen, it showed no trace of the latter; in another experiment, in which the gas of the volcancitos was kept for many hours in a small bell-glass turned down in water, it showed rather more than one per cent. of oxygen, which was probably derived from the water, and had become accidentally mixed with it.

According to these results of analysis, I then stated that I considered (not altogether incorrectly) the gas of the volcancitos of Turbaco to be nitrogen, which might be mixed with a small quantity of hydrogen. I expressed at the same time in my journal regret, that in the then state of chemical knowledge (in April 1801)

there was no known way of determining, in a mixture of nitrogen and hydrogen, the relative proportions of each. A method of doing this, so that an admixture of three thousandths of hydrogen could be detected, was discovered four years afterwards by Gay-Lussac and myself. (293) In the half century which has elapsed since my visit to Turbaco and my astronomical survey of the Magdalena River, no traveller examined the above-described small mud-volcanoes scientifically; until, at the end of December 1850, my friend Joaquin Acosta, (294) who was acquainted with modern geology and chemistry, made the important observation that,—"at that time the cones exhaled a bituminous odour; that some petroleum floated on the surface of the water in the orifices; and that the gas which rose from each of the volcancitos was inflammable." Of all this there was no trace in my time. Acosta asks whether these circumstances indicate a real alteration produced in the phænomena by subterranean processes, or whether the discrepancy arises merely from error in the earlier experiments? I should have freely admitted the latter to have been a probable explanation, if I had not preserved the leaf of the journal in which I noted the experiments in detail on the same morning on which they were made. (295) I find nothing therein which could now give me any doubts respecting them; and the experience above alluded to, *i. e.* that (according to Parrot's account) "the gas of the mud-volcanoes of the peninsula of Taman had, in 1811, the property of preventing combustion; that a glimmering splinter was extinguished in it; and that the bubbles which rose a foot thick, could not be made to ignite in bursting,"—whereas at the same place, Göbel,

in 1834, saw the gas easily kindled and burning with a clear blue flame, — leads me to believe that, in different stages, the exhalations undergo chemical alterations. Mitscherlich, at my request, has recently determined the limits of inflammability in artificially prepared mixtures of nitrogen and hydrogen gases. The result was that mixtures of one part hydrogen and three parts nitrogen would not only be ignited by a light being brought near to them, but also would continue to burn: when the proportion of nitrogen was augmented so that the mixture consisted of one part hydrogen and three and a half parts nitrogen, it would still ignite, but would not continue to burn. It was not until the mixture consisted of one part hydrogen and four parts nitrogen that no ignition at all took place. The gaseous exhalations, which, on account of their easy inflammability and the colour of their light, are usually called exhalations of pure and carburetted hydrogen, need therefore only in fact have as much as one third part of that gas in their composition. In the more rare mixtures of carbonic acid and hydrogen, on account of the capacity for heat of the former, the limit of capability of ignition is modified. Acosta is right in throwing out the question, "whether a tradition subsisting among the natives of Turbaco, descendants of the Indios de Taruaco, according to which the volcancitos were once all burning, and were all changed from 'volcanos de fuego' into 'volcanos de agua' by the adjurations of a pious monk, and being sprinkled by him with holy water, ([296]) may not have related to a former condition which is now returning?" Analogous examples are presented by, at one time the eruption of great flames, and

subsequently very peaceful mud-volcanoes, in the region of the old continent already referred to. (Taman, 1793; on the Caspian at Jokmali, 1827; at Baklichli, 1839; and at Kuschtschy in the Caucasus, 1846.)

The apparently small phænomenon of the salses of Turbaco has gained in geological interest by the great outbursts of flame and changes of surface, which in 1839 extended between thirty and forty miles N.N.E. of Carthagena to the port of Sabanilla, not far from the mouth of the great Magdalena River, and for the knowledge of which we are also indebted to the late lamented Artillery-Colonel, Acosta. The proper central point of this latter phænomenon appears to have been situated in the narrow peninsula called Cape Galera Zamba, which runs out six or eight miles into the sea. In the middle of this tongue of land there stood a conical hill having a crater-like opening, from which smoke (vapours and gases) sometimes rose with such vehemence, that boards and large pieces of wood, which had been thrown into it, were expelled and hurled to a great distance. In the year 1839 this cone disappeared, its disappearance being accompanied by a considerable outbreak of fire; and the whole peninsula of Galera Zamba became an island, separated from the mainland by a channel more than thirty feet deep. The surface of the sea remained tranquilly in this state until, on the 7th of October 1848, without any earthquake being felt in the country round, there appeared a second great outburst of flames, ([297]) which lasted several days and were visible to distances of between forty and fifty miles. The salse emitted only gases, not solid or liquid substances. When the flames had ceased, the sea-bottom was found to have been

upheaved in the form of a small sandy island, which, however, disappeared again soon afterwards. More than fifty "volcancitos" (cones similar to those of Turbaco) now surround (in some cases at a distance of sixteen or twenty miles) the submarine gas-volcano of the Galera Zamba. This may well be regarded as, in geological respects, the principal seat of the volcanic activity which throughout the low-lying district of Turbaco, and extending over the delta of the Rio Grande de la Magdalena, strives to place itself in contact with the atmosphere.

The similarity of the phænomena shown, in the different stages of their activity, by the salses, mud-volcanoes, and gas-springs on the Italian peninsula, in the Caucasus, and in South America, is displayed over vast tracts of country in the Chinese empire. There the art of man has, since very early times, utilised these great natural supplies; and for this object had arrived long since at the very ingenious invention with which Europeans only became acquainted at a far later period,— that of "Chinese rope-boring." These borings, several thousand feet deep, were effected by the simplest application of man's bodily power, or rather of his weight. I have elsewhere ([298]) treated in detail of this invention, as well as of the "fire-springs" (Ho-tsing), and of the fire-mountains (Ho-schan), of Eastern Asia. Men bore for water, salt, and combustible gas, from the south-west provinces of Yun-nan, Kuang-si, and Szu-tchuan on the borders of Thibet, to the northern province of Schan-si. The gas burns with a reddish flame and often diffuses a bituminous smell: it is conveyed to a distance, sometimes through pipes of bamboo, sometimes in port-

able tubes also of bamboo, to be used in salt-works, in warming houses, or in lighting streets. In some rare instances the supply has suddenly become exhausted, or has been stopped by earthquakes. Thus it is known that a celebrated Ho-tsing, situated south-west of the town of Khiung-tscheu (N. lat. 50° 27′, long. 103° 27′ E.), a saline spring which burnt with noise, became extinct in the 13th century, after having supplied lights for the country round for 1100 years. In the province of Schan-si, which is very rich in stone coal, some coal-beds are on fire. The "fire mountains" (Ho-schan), are found over a large part of China. The flames often rise, at great heights above the sea (for example, in the rocks of the Py-kia-schan, at the foot of a mountain covered with perpetual snow in lat. 31° 40′), from long, open, inaccessible fissures or clefts: a phænomenon which recalls the "perpetual fires of Schagdagh" in the Caucasus.

In the island of Java, in the province of Samarang about 12 miles from the north coast, there are salses which resemble those of Turbaco and Galera Zamba. Hillocks, from 27 to 33 feet high (which undergo frequent changes), cast up mud, salt water, and a remarkable mixture of hydrogen and carbonic acid gases, ([299]) a phænomenon which must not be confounded with the great and devastating torrents of mud, poured forth on the rare occurrence of eruptions of the colossal true volcanoes of Java (Gunung Kelut and Gunung Idjen). Some mephitic grottoes, or springs of carbonic acid gas, in the island of Java, are still very celebrated, in great measure from the exaggerated descriptions of some travellers, as well as from a connection, suspected by Sykes

and by Loudon, with the fabulous stories of the Upas or poison-tree. The most remarkable of these, situated in the mountains of Diëng, near Batur, has been scientifically described by Junghuhn; it is called Pakaraman, the Island Valley of Death. It is a fallen-in, funnel-shaped hollow, situated on the side of a mountain, in which the height of the unrespirable stratum of carbonic acid gas varies very much at different seasons. Skeletons of wild swine, tigers, and birds are often found there. (300) The poison-tree, pohon or pühn, the ûpas of the Malays (the Antaris toxicaria of the traveller Leschenault de la Tour), and its harmless exhalations, have nothing whatsoever to do with these fatal effects. (301)

I will conclude this section on salses and on gas and vapour springs with a description of a case which may be interesting to geologists on account of the kind of rock from which hot sulphureous vapours are developed. When making the delightful, but somewhat arduous, passage across the central Cordillera of Quindiu, from the valley of the Rio Magdalena to the Cauca valley (it took me 14 or 15 days' foot travelling, sleeping always in the open air, to pass over the crest, 11,497 feet above the sea), I visited the Azufral, situated, at a height of 6810 feet, on the west of the station of El Moral. In a rather dark-coloured mica-slate, which is superposed on a garnet-bearing gneiss, and, together with it, surrounds the high granite cupolas of La Ceja and La Garita del Paramo, I saw in the narrow valley (Quebrada del Azufral) warm sulphureous vapours issue from the clefts in the rock. As the vapours are mixed with sulphuretted hydrogen and much carbonic acid gas, a stupefying sensation of giddiness, felt on stooping down

to measure their temperature, warns the observer not to linger. The temperature of the sulphureous vapours was 117°·7, that of the air 69°, and that of the "sulphur rivulet," which, perhaps, in its upper portion may be cooled by the snow-water from the volcano of Tolima, 84°·6. The mica-slate which contains pyrites is interspersed with sulphur in pieces. The sulphur prepared for sale is obtained chiefly from an ochrous-yellow clay mixed with native sulphur and weathered mica-slate. The labourers (who are Mestizos) suffer in their eyes and muscles. When Boussingault visited the Azufral de Quindiu, 30 years later, in 1831, the temperature of the vapours (which he analysed chemically)([302]) had diminished so much that it was actually below that of the free air, the latter being 71°·6, while the former was from 66°·2 to 68°. The same excellent observer saw, in the Quebrada de Aguas calientes, the locality where the trachyte of the adjacent volcano of Tolima breaks through the mica. The also eruptive black trachyte of the volcano of Tunguragua was distinctly seen by myself covering the garnetiferous greenish mica-schist, near the rope bridge of Penipe. As sulphur had not previously been seen in Europe in what were formerly called "primitive rocks," but only in tertiary limestone, gypsum, conglomerates, and in true volcanic rocks, its occurrence in the Azufral of Quindiu (N. lat. 4½°) is noteworthy, and the more so, because it is repeated south of the equator, between Quito and Cuenca, on the northern declivity of the Paramo del Assuay. In the Azufral of Cerro Cuello (S. lat. 2° 13′) I saw, also in the mica-slate, at a height of 7980 feet, a very considerable bed of quartz([303]) richly interspersed with sulphur. At the

period of my visit pieces of sulphur were only found from $6\frac{1}{4}$ to $8\frac{1}{2}$ inches in size; pieces of three or four feet had been found earlier. Even a spring of naphtha may be actually seen to rise from mica-schist at the bottom of the sea in the Gulf of Cariaco, near Cumana. The naphtha gives a yellow colour to the surface of the sea for a distance of more than 1000 feet, and I found its smell diffused so far as the interior of the peninsula of Araya. ([304])

If we now cast a last glance on that kind of volcanic activity which manifests itself by the emission of vapours and gases, either with or without igneous phænomena, we find sometimes great affinity, and sometimes an equally remarkable diversity, in the escaping substances, according as the high internal temperature has exerted its modifying influence on the mutual action either of homogeneous or of highly diversified materials. The substances which this low degree of volcanic activity brings to the surface are — aqueous vapour or steam in large quantities, chloride of sodium, sulphur, carburetted and sulphuretted hydrogen, carbonic acid and nitrogen, naphtha (colourless, yellow, or as brown petroleum), boracic acid gas, and clay of the mud-volcanoes. The great diversity of these substances, of which some, however (common salt, sulphuretted hydrogen, and petroleum), are almost always associated together, shows the inappropriateness of the term "salse," derived from Italy, where Spallanzani had the great merit of first directing the attention of geologists to the previously disregarded phænomena of this kind in the territory of Modena. The terms "gas-springs" and "vapour-springs" are more generally expressive. While doubtless many

may be regarded in the light of "fumeroles" connected with extinct volcanoes, more particularly as springs of carbonic acid gas are a characteristic of one of the latest stages of such volcanoes, others, on the other hand, as naphtha-springs, appear to be wholly independent of genuine lava-erupting volcanoes. They follow (as Abich has already shown in the Caucasus) definite directions over extensive spaces, breaking forth from fissures, on the plain, and even in the deep basin of the Caspian, as well as on mountain heights of nearly 8000 feet. Like volcanoes proper, their apparently slumbering activity sometimes suddenly displays itself by the bursting forth of columns of flame, which spread terror afar. They show the same successive stages in both continents, at parts of the earth very remote from each other; but hitherto experience has not authorised us to regard them as foreshowing the rise of true volcanoes erupting lavas and scoriæ. Their activity is of another kind; perhaps originating at lesser depths, and dependent on other chemical processes.

d. *Volcanoes, according to their Diversity in Shape and Activity—Action through Fissures and Maars—Encircling Ridges round Craters of Elevation—Volcanic, conical, and dome-shaped Mountains, with open or unopened Summits — Diversity of Rocks through which Volcanoes act.*

(Enlargement of the Picture of Nature in Cosmos, Vol. I. p. 213—235.)

Among the manifold kinds of manifestation of force in the reaction of the interior of our planet against its

outermost strata, the most powerful is that exhibited by volcanoes proper, *i.e.* openings through which (besides gases) solid substances of various kinds are brought in a state of igneous fluidity from unknown depths to the surface, where they issue forth either as streams of lava, or as scoriæ, or in a state of the finest comminution, when they are called "ashes." When, according to the sense attached by ancient usage to the expressions volcano and burning mountain, these are employed as synonymous terms, the idea of volcanic phænomena is connected, according to what was a very generally received impression, with the image of an isolated conical mountain, having at its summit a circular or oval opening or crater. Such views lose, however, some of their generality, when the observer has the opportunity of wandering through volcanic regions of many thousand square miles in extent; as, for example, the entire central part of the Mexican highlands between the Peak of Orizaba, Jorullo, and the shores of the Pacific; or in Central America; or in the Cordilleras of New Granada and Quito between the volcano of Purace near Popayan, that of Pasto, and Chimborazo; or in the Caucasus between Kasbegk, Elbourz, and Ararat. In Lower Italy, between the Phlegræan Fields of the Campanian mainland, Sicily, the Lipari and Ponza Isles, as well as in the Greek islands, the intervening land has partly not been upheaved at the same time, and partly has been since swallowed up by the sea.

In the above-mentioned large districts in America and in the Caucasus we find erupted masses (true trachytes, not conglomerates of trachyte), streams of obsidian, and blocks of pumice-stone obtained by

quarrying (not decomposed rolled pumice-stone brought by water), appearing to be quite independent of the mountains, which are seen rising only at a considerable distance. Why may we not suppose that, in the progressive cooling down of the heat-radiating outer strata of the earth, before either isolated mountains or mountain chains were yet upheaved, the surface may have been variously split up and fissured? and why may not these fissures have extruded igneously fluid masses which have hardened into volcanic and other rocks (trachytes, dolerites, melaphyres, pearlstone, obsidian, and pumice)? Part of these, originally in horizontal beds (trachytes or dolerites which had burst forth in a tenacious semi-fluid state, as from earth-springs), (305) may, at the later upheaval of volcanic cone- and dome-shaped mountains, have been thrown into a broken and precipitous state, not seen in the later lavas which have originated in burning mountains or volcanoes proper. Thus, to recall first a well-known European example,— in the Val del Bove on Etna (a hollow which cuts deep into the interior of the mountain), the angle of "fall" of the lava strata, alternating very regularly with rolled masses, is from 25° to 30°; whereas that of the streams of lava which cover the surface of Etna, and which have flowed since its upheaval as a mountain, have, on a mean of thirty streams, according to Elie de Beaumont's exact determinations, only an angle of descent of from 3° to 5°. Such differences point to the existence of very ancient volcanic formations which had burst forth from fissures before the elevation of the existing volcano. Classical antiquity also presents us with an example of a remarkable phænomenon of this class,

which showed itself in a wide plain in a district remote from any active or extinct volcanoes; in the island of Eubœa, the modern Negropont. "The violent shocks of earthquake, which partially shook the island, did not cease until an abyss, opened in the plain of Lelantus, poured forth a stream of glowing mud (lava)." ([306])

If, as I have long been disposed to conjecture, we may ascribe to a first fissuring of the deeply disturbed earth-crust the oldest formations of eruptive rocks (often perfectly similar in mineral composition to recent lavas), then these fissures, as well as the craters of elevation of later origin and already less simple, must be looked upon only as volcanic openings through which erupted masses have flowed, and not as volcanoes proper. The principal character of these latter consists in a permanent, or at least from time to time renewed, connection between the deep-seated focus or source of igneous action, and the atmosphere. The volcano requires for this purpose a particular kind of framework; for, as Seneca says very appositely in a letter to Lucilius, "ignis in ipso monte non alimentum habet, sed viam." ([307]) In regard to volcanoes, therefore, the form-giving, or shaping, activity is exerted by the upheaval of the ground; not (as was formerly and almost exclusively believed) in *building up by successive accumulation* of scoriæ and strata of lava deposited one above another. The resistance which the fiery-fluid masses, pressed in too great abundance against the surface, find in what is to be the channel of eruption, occasions the augmentation of the upheaving force. There arises a "bubble-shaped pushing-up of the ground," as is indicated by the regular outward

slope of the upheaved strata. A mine-like explosion, the bursting of the central and highest portion of the convex swelling of the ground, produces sometimes only what Leopold von Buch has termed a "crater of elevation;" (308) *i.e.* a crater-shaped, round or oval, depression bounded by an "elevation-circus," a ring-shaped, and in most cases partly broken down, rampart or encircling ridge, and sometimes also at the same time — when the structure of a permanent volcano is to be completed — a dome-shaped or conical mount in the middle of the crater of elevation. This inner mount is, in the greater part of such cases, open at its summit, and on the floor of this opening (or the floor of the crater of the permanent volcano), there rise non-permanent hills of erupted substances and scoriæ, small and great "cones of eruption;" in Vesuvius these sometimes rise much higher than the crater-walls of the cone of elevation. It is not always, however, that all the witnesses to the first eruption — all the different parts of the old framework or scaffolding, such as I have here described, are preserved. In many of the greatest and most active volcanoes the high escarpment forming the periphery of the crater of elevation cannot be traced even in fragments or ruins.

A great service has been rendered in modern times, not only by the careful comparison of volcanoes situated at remote distances from each other, and by the more exact examination of their several relations of form; but also by the introduction of more definite expressions, whereby significant differences in relief, as well as in the manifestations of volcanic activity, are distinguished apart. If one is not decidedly averse to all classification,—

because, notwithstanding the endeavour to generalise, it still must always rest on imperfect inductions,—one may represent to oneself the bursting forth of igneously fluid masses and solid substances, accompanied by vapours and gases in various manners. Passing from the more simple to the more complex phænomena, we will specify, first, eruptions from fissures, not giving rise to a series of detached cones, but pouring forth substances in a state of tenacious semi-fluidity, forming superposed volcanic masses; secondly, eruptions through cones of accumulation without surrounding escarpment, but yet pouring forth streams of lava, as was the case for five years at the devastation of the island of Lancerote in the first half of the last century; thirdly, craters of elevation with upheaved strata without any central cone, sending forth streams of lava only on the outer side of the escarpment, never from the interior, which is soon closed by falling in; fourthly, closed dome-shaped mountains, or cones of elevation open at the summit, either surrounded by an at least partially preserved encircling ridge, as at the Peak of Teneriffe, in Fogo, and Rocca Monfina, or else quite without circumvallation and without any crater of elevation, as in Iceland, (309) in the Cordilleras of Quito, and in the middle part of Mexico. The open cones of elevation of this fourth class maintain a permanent more or less active communication, in indeterminate intervals of time, between the heated interior of the earth and the external atmosphere. Dome-shaped trachyte and dolerite mountains with closed summits seem, according to what I have been able to observe, to be more numerous than open cones, either still active or extinct, and much more numerous than volcanoes proper. Dome-

and bell-shaped mountains, like Chimborazo, Puy de Dome, Sarcouy, Rocca Monfina, and Vultur, give to the landscape in which they are seen a peculiar character, by which they contrast agreeably with the schistose Horns or the jagged forms of calcareous rock.

The elevation of such a dome-shaped mount without opening is indicated with great clearness in the very graphic description in which Ovid has preserved the tradition of a great volcanic event in the peninsula of Methone. "The powerful force of winds imprisoned in dark caverns, seeking in vain an outlet, caused the inflated ground to swell upwards, as when a bladder or a goat-skin is filled with air. The high swelling by slow hardening has remained a hill." I have remarked elsewhere how entirely this Roman description differs from Aristotle's account of the volcanic event at Hiera, a newly arisen Æolian island: "the subterranean powerfully urging breath" is indeed here also described as raising a hill, but also as "afterwards breaking it up and pouring from it a fiery rain of ashes." Here the elevation is distinctly described as preceding the igneous outburst. (Cosmos, Vol. I. note 230.) According to Strabo it would seem as if the dome-shaped hill of Methana had also opened in a fiery eruption, at the termination of which an agreeable odour diffused itself each night. It is a striking circumstance that a sweet smell was remarked under similar conditions at the volcanic eruption of Santorin in the autumn of 1650, and is mentioned in a sermon, preached soon afterwards by a monk, which has been preserved.(310) May not such an odour indicate naphtha? The same thing is spoken of by Kotzebue in his Russian Voyage of Dis-

covery, on the occasion of an igneous eruption, in 1804, of the island-volcano of Umnack, then newly risen from the sea, in the Aleutian Archipelago. At the great eruption of Vesuvius on the 12th of August 1805, which Gay-Lussac and I observed together, he perceived from time to time a predominating bituminous smell in the burning crater. I have here brought together these few and hitherto little regarded facts, because they help to confirm the close interconnection of all manifestations of volcanic activity, linking salses and naphtha-springs with actual volcanoes.

Encircling ridges analogous to those of craters of elevation, show themselves in kinds of rock very different from trachyte, basalt, and porphyritic schist; for example, according to Elie de Beaumont, in the granite of the French Alps. The Oisans mass of mountains, to which the highest summit in France, (311) Mont Pelvoux near Briançon (12,905 feet), belongs, forms a circus of thirty-two geographical miles in circumference, in the middle of which lies the little village of La Bérarde. The steep walls of the circus rise to a height of 9600 feet. The circumvallation itself is gneiss; all within it is granite. (312) In the Swiss and Savoy Alps the same form is shown in several cases, in smaller dimensions. The Grand Plateau of Mont Blanc, on which Bravais and Martins encamped several days, is a closed circus, or amphitheatre, 12,810 feet high, with an almost even floor, out of which the great summit-pyramid rises. (313) The same upheaving forces produce similar forms, though modified by the composition of the rocks on which they have been exerted. The valleys of elevation, described by Hoffmann, Buck-

land, Murchison, and Thurmann, in the sedimentary rocks of the North of Germany, in Herefordshire, and in the Jura Mountains of Porrentruy, are connected with the phænomena which have been here described; as are also, though with a less measure of analogy, some high plains in the Cordilleras, closed in on all sides by mountains, on which are situated the towns of Caxamarca (at 9362 feet above the sea), Bogota (8728 feet), and Mexico (7469 feet); and in the Himalaya the valley of Cashmere, 5820 feet above the sea.

Less nearly related to the "craters of elevation" than the above described simplest form of volcanic activity, are the numerous caldron-like depressions, surrounded by but little raised margins which they have themselves formed, which are found among the extinct volcanoes of the Eifel, in non-volcanic rock, Devonian schist, and which are called "Maars." "They are as it were mine-funnels,—evidences of mine-like explosions,"—recalling the singular phænomenon described by myself at the earthquake of Riobamba (4th of February 1777), when the bones of men were cast forth on the hill of La Culca. ([314]) Where, in particular cases, such ancient explosion-craters situated at no great elevation, in the Eifel, in Auvergne, or in Java, are filled with water, they may bear the name of Lake-craters, which has been given to them; but that term ought not to be regarded as synonymous with the German "Maar," inasmuch as on the summits of the highest volcanoes, on true cones of elevation, in extinct craters, (for example, on the Mexican volcano of Toluca at 12,245 feet, and on Mount Elbourz in the Caucasus at 19,716 feet,) small lakes were found by myself and

by Abich. In the Eifel volcanoes, two kinds of volcanic activity, of very different age, must be carefully distinguished from each other, the strictly so-called volcanoes, sending forth streams of lava, and the feebler explosion phænomena of the Maars. To the first belong the basaltic, oliviniferous, vertically columnar lava-stream in the Uesbach valley near Bertrich; [315] the volcano of Gerolstein, situated in a limestone containing dolomite, embedded in the Devonian grauwacke schist; and the long ridge of the Mosenberg (1753 feet above the sea) not far from Bettenfeld, west of Manderscheid. The last-named volcano has three craters, of which the first and second (the northernmost ones) are perfectly round, and their floors covered with turf-bog; but from the third (southernmost) [316] crater there has descended a considerable reddish brown stream of lava, which lower down, towards the valley of the Little Kyll, has become columnar. A remarkable phænomenon, generally speaking quite foreign to lava-yielding volcanoes, is, that neither at the Mosenberg, nor at the Gerolstein, nor in the other volcanoes proper of the Eifel, are the lava streams seen to be surrounded at their origin by a trachytic rock, but on the contrary, so far as they are accessible to observation, they seem to come directly from the Devonian beds. The surface of the Mosenberg in no way betrays what is hidden in its depths. The augitic scoriæ, which pass connectedly into basaltic streams, contain small burnt pieces of schist, but no trace of enclosed trachyte. Nor are any such enclosures to be found even in the crater of the Rodderberg, though it is so near to the greatest mass of trachyte in the neighbourhood of the Rhine, the Siebengebirge.

"The Maars," as is acutely remarked by Captain von Dechen, "seem by their formation as if they belonged to nearly the same epoch as streams of lava from true volcanoes. Both are situated near deeply cut valleys. The lava-yielding volcanoes were certainly active at a period when the valleys had already received very nearly their present form; and we actually see the oldest lava-streams of the district falling precipitously into the valleys." The Maars are surrounded by fragments of Devonian schist and of heaped-up grey sand and tufa margins. The Laacher See, — whether we regard it as a great Maar, or as it is regarded by my friend C. von Oeynhausen as part of a great caldron-valley in the clay-slate, — shows on its surrounding borders some volcanic scoriæ; as at the Krufter Ofen, at the Veitskopf and the Laacher Kopf. But it is not only by the entire absence of streams of lava (as they are observed in the Canary Islands, at the outer margin of true craters of elevation, or in their immediate neighbourhood), or by the inconsiderable height of their margin, that the Maars are distinguished from craters of elevation; their borders are also wanting in that regular, always convex, outward slope in the stratification, which is a consequence of upheaval. As has been already remarked, the Maar depressions in the Devonian schists appear like mine-funnels into which, immediately after the violent explosion of hot gases and vapours, the greater part of the light loose masses emitted (Rapilli) again fell back. I name here, as examples, only the Immerath Maar and those of Pulver and Meerfeld. In the midst of the first, of which the dry floor at two hundred feet deep is cultivated, are

situated the two villages of Upper and Lower Immerath. Here are found in the volcanic tufa around, just as at the Laacher See, mixtures of felspar and augite forming spheres or nodules, in which black and green vitreous particles are interspersed. Similar balls of mica, hornblende and augite, full of vitrifactions are also found in the tufa margin of the Pulver Maar, (near Gillenfeld), which, however, is entirely transformed into a deep lake. The regularly circular Meerfelder Maar, covered partly with water and partly with bog, is geologically distinguished by the vicinity of the three craters of the great Mosenberg, from the southernmost of which a lava-stream has flowed. The Maar is, however, 640 feet lower than the long ridge of the volcano, and is at its northern end; moreover it is not in the axis of the line of craters, but is more to the north-west. The mean height of the Maars of the Eifel above the sea falls between 922 feet, the height of the Laacher See (if *it* be regarded as a Maar), and 1588 feet, the height of the Mosbrucher Maar.

As this is more particularly the place at which to call attention to the general uniformity and accordance in the *substances* produced by volcanic activity, while there is the greatest diversity in the *forms* of the outward framework belonging to that activity, (as the Maars above spoken of, — elevation craters, — and conical volcanoes open at the summit,) I will here refer to the striking abundance of crystallised minerals which the Maars brought to the surface at their first explosion, and which now lie partly buried in the tufa. This abundance is particularly great round the Laacher See; but there are also others, for instance, the Immerather and the

Meerfelder Maar, (the latter of which is rich in balls of olivine,) which contain many fine crystalline masses. We will cite here Zircon, Hauyne, Leucite, [317] Apatite, Nosean, Olivine, Augite, Ryacolite, common Felspar (Orthoclase), glassy Felspar, Mica, Sodalite, Garnet, and Titanite. If the number of fine crystallised minerals at Vesuvius is much greater, (Scacchi counts 43 kinds,) it should not be forgotten that very few of them were emitted from the volcano; that the greater part of them belong, according to Leopold von Buch's opinion, [318] "not to Vesuvius, but to a tufa-covering, extending far beyond Capua, which was upheaved by the cone of Vesuvius together with itself at its elevation, and was probably the product of a submarine volcanic action hidden deep in the interior of the earth."

Certain determinate directions of the different kinds of phænomena produced by volcanic activity may also be distinctly traced in the Eifel. "The eruptions of lava in the high Eifel took place along a fissure nearly 28 miles long, running from south-east to north-west, from Bertrich to the Goldberg near Ormond; on the other hand, the Maars from the Meerfelder Maar to Mosbruch and the Laacher See follow a direction from south-west to north-east. These two leading lines of direction intersect each other in the three Maars of Daun. Round the Laacher See no trachyte is visible at the surface. The presence of this rock in the depths below is only indicated by the peculiar nature of the whole felspathic pumice of Laach, as well as by the ejected balls of augite and felspar. The only visible trachytes of the Eifel, however, composed of felspar with large crystals of hornblende, are distributed between

basaltic mountains or hills; as in the Seilberg (1892 feet high), near Quiddelbach, on the Height of Struth near Kelberg, and in the wall-like ridge of Reimerath near Boos."

Next after the Lipari and Ponza Islands few parts of Europe have produced more pumice than this part of Germany, which, with a comparatively small elevation, presents such different forms of volcanic activity, Maars or craters of explosion, basaltic hills, and lava-emitting volcanoes. The principal mass of the pumice is between Niedermendig and Sorge, Andernach and Rübenach; the principal mass of the "Duckstein" or Trass (a very recent conglomerate deposited by water) is in the Brohlthal, from its mouth at the Rhine up to Burgbrohl, near Plaidt and Kruft. The trass formation of the Brohlthal contains, besides fragments of graywacke schist and pieces of wood, fragments of pumice which are in no way distinguishable from the superficial covering of the district, and even of the trass itself. I have always doubted, notwithstanding some analogies which the Cordilleras might seem to present, whether the trass could be ascribed to eruptions of mud from the lava-emitting volcanoes of the Eifel. I rather conjecture, with H. von Dechen, that the pumice was thrown out dry, and that the trass was formed in the same manner as other conglomerates. "There is no pumice in the Siebengebirge, and the great eruption of pumice in the Eifel (the principal mass of which still overlies the Loess, and in parts alternates with it) may, according to the conjecture to which the local relations tend to lead us, have taken place in the valley of the Rhine above Neuwied, in the great Neuwied basin,

perhaps near Urmits, on the left side of the Rhine. From the great friability of this substance, the later action of the river may have entirely removed all traces of its place of origin or eruption. In the whole line of the Eifel Maars, as well as in the Eifel volcanoes, from Bertrich to Ormond, no pumice is found. That of the Laacher See is confined to the hills of its shores, and at the other Maars the small pieces of felspar, lying in the volcanic sand and tufa, do not pass into pumice."

We have already alluded to the relations which the age of the Maars, and that of the very different eruptions of lava, bear to the age of the formation of the valleys. "The trachyte of the Siebengebirge seems much older than the formation of the valleys, and even than the Rhenish browncoal. Its origin is unconnected with the rending open of the Rhine valley, even supposing we should ascribe the formation of that valley to the opening of a fissure. The valley is much more recent in its origin than the Rhenish browncoal, and more recent than most of the Rhenish basalt; on the other hand, it is older than the volcanic eruptions of lava-streams, and older than the great outburst of pumice, and than the trass. Basaltic formations decidedly come down to a more recent period than do those of trachyte; and the principal mass of the basalt is thus to be looked upon as younger than the trachyte. On the present sides of the valley of the Rhine many basaltic groups (those of Unkeler Steinbruch, Rolandseck, and Godesberg) were, it may be supposed, first laid bare by the opening of the valley, as it is probable that they were previously enclosed in the Devonian graywacke hills."

The Infusoria (whose general distribution over our

globe, on continents, in the greatest depths of the ocean, and in the highest strata of the atmosphere, as demonstrated by Ehrenberg, constitutes one of the most brilliant discoveries of our age) have in the Eifel their principal seat in the rapilli, trass-beds and pumice-conglomerates. Silicious-shelled organisms abound in the Brohlthal and in the erupted masses of Hochsimmern; sometimes in the trass they are mingled with *uncarbonised* branches of Coniferæ. The whole of this minute organic life is, according to Ehrenberg, a fresh-water formation; it is only exceptionally, in the uppermost deposit of the friable yellowish Loess, at the foot and on the sides of the Siebengebirge, that marine Polythalamia are found, indicating the brackish character of an ancient coast district. (319)

Is the existence of the phænomenon of Maars confined to Western Germany? Count Montlosier, who was well acquainted with the Eifel by his own observations in 1819, and recognised the Mosenberg as one of the finest volcanoes which he had ever seen, regards (like Rozet) the Gouffre de Tazenat, the Lac Pavin, and the Lac de la Godivel, in Auvergne, as Maars, or explosion-craters. They are hollowed out of very different kinds of rock, granite, basalt, and domite (trachytic rock), and are surrounded at the margin by scoriæ and rapilli. (320)

The framework or scaffolding, which the more powerful eruptive activity of volcanoes may be said to construct by the upheaving and uplifting of the ground, and by the streams of lava poured forth, has been observed under at least six different forms, and these different forms are found distinctly repeated in the most distant regions of the earth. To a native of a volcanic

district, born amidst basaltic and trachytic mountains, these once familiar forms, when seen again in a strange land, often seem, as it were, to greet him with a home-like welcome. The forms of mountains are among the most important of the elements which determine the "physiognomy of nature;" they give to the aspect of the region in which they are seen, according as they are adorned with vegetation or soar aloft in desert nakedness, a cheerful, or a grave and majestic character. I have very lately tried to place side by side in a separate atlas a number of sketches, taken from drawings of my own, of the Cordilleras of Quito and Mexico. As basalt appears sometimes in cones rounded off at the summit, sometimes as twin mountains placed close to each other but of unequal height, sometimes as a long horizontal ridge having two higher rounded summits at either extremity; so in the trachyte we distinguish pre-eminently the majestic dome ([321]) of Chimborazo (21,422 feet), a form not to be confounded with that of the also unopened, but more slender, "bell-shaped" mountains. The conical form is seen in the greatest degree of perfection ([322]) in Cotopaxi (18,877 feet); and next to it in Popocateptl ([323]) (17,726 feet), as seen from the beautiful shores of the lake of Tezcuco, or from the top of the ancient Mexican terraced pyramid of Cholula; and in the volcano ([324]) of Orizaba (17,374, or, according to Ferrer, 17,879 feet). A strongly truncated cone-shape ([325]) is seen in the Nevado de Cayambe-Urcu (19,365 feet) immediately under the equator, and also in the volcano of Tolima (18,128 feet), as seen rising from behind the primeval forest, from the foot of the Paramo of Quindiu, near the little town of Ibague. ([326])

The volcano of Pichincha (15,890 feet), to the surprise of the geologist, forms a long-drawn ridge, at one extremity of which, a little higher than the rest of the mountain, is situated the wide and still burning crater. ([327])

Fallings in of the crater-walls, occasioned by great volcanic spasms of activity, in which they are rent asunder by mine-like explosions from the depths below them, give rise in conical mountains to very strange and contrasted forms: it has been thus in the case of the Carguairazo (15,666 feet), where a fissure into "double pyramids," of more or less regularity of form, took place by a sudden falling in on the night of the 19th of July 1698; ([328]) and in that of the finer pyramids of Ilinissa, (17,437 feet) ([329]). In a similar manner the upper portion of crater-walls may become broken into a rude kind of battlement, and subsequent commotions may leave parts only of the same homogeneous mountain standing as partially detached towers or peaks; and thus at Capac-Urcu, Cerro del Altar, now only 17,456 feet, two very similar peaks, rising in emulation of each other, allow us to conjecture the earlier primitive form of the mountain. A tradition has been generally preserved among the natives of the highlands of Quito, between Chambo and Lican, and between the mountains of Condorasto and Cuvillan, that fourteen years before the invasion of Huayna Capac, son of the Inca Tupac Yupanqui, the summit of the last-named volcano, after eruptions which lasted uninterruptedly for seven or eight years, fell in, covering the whole of the plateau on which New Rio-bamba is situated with pumice and volcanic ashes. Originally higher than Chimborazo, it was called in the

Inca or Quichua language, "Capac," *i. e.* King or Prince of Mountains (urcu), because its summit was seen to rise higher than any other above the lower limit of the snowy region. ([330]) Mount Ararat, whose summit, 17,080 feet high, was reached by Friedrich Parrot in 1829, and by Abich and Chodzko in 1845 and 1850, forms, like Chimborazo, an unopened dome. Its large streams of lava broke forth far below the snow line. An important feature in the shape of Ararat is formed by the deep lateral hollow of Jacob's Valley, which may be compared to the Val del Bove in Mount Etna. It is here that, according to Abich, the internal structure of the nucleus of the trachytic bell-shaped mountain is first visible, as this nucleus and the elevation of the whole mountain are much more ancient than the streams of lava. ([331]) The mountains of Kasbegk and Tschegem, which rise from the same leading Caucasian ridge, running E.S.E. to W.N.W. as does Elburuz, or Elbourz (19,716 feet high), are also cones without craters on their summits: on the summit of the last-named colossal mountain there is a crater-lake.

As cones and domes are in all parts of the world much the most frequent forms, it is the more surprising to see, as a solitary instance in the group of volcanoes around Quito, the long ridge of the volcano of Pichincha. I occupied myself long and carefully with examining its form, and besides the view of its profile founded on many measurements of angles, I have published also a topographic sketch of its cross-valleys. ([332]) Pichincha forms a wall more than eight geographical miles long, consisting of black trachytic rock (composed of augite and oligoclase), upheaved over

a fissure in the westernmost Cordillera nearest to the Pacific Ocean, without the direction of the axis being coincident with that of the Cordillera. The lofty wall is surmounted, castle-like, by three successive summits from south-west to north-east, called Cunturguachana, Guagua-Pichincha (or the child of the old volcano) and el Picacho de los Ladrillos. The proper volcano is termed "the Father," or "Old Man," "Rucu-Pichincha." It is the only part which enters the region of perpetual snow, rising to a height which exceeds that of Guagua-Pichincha (the child), by about 190 or 200 feet. Three tower-like rocks surround the oval crater, which lies a little to the south-west, therefore, out of the immediate axis, of a rocky wall, of which the mean height is 15,673 feet. In the spring of 1802 I reached the summit of the eastern tower in company with the Indian Felipe Aldas. We stood alone there, on the outermost margin of the crater, about 2450 feet high above the floor of the fiery abyss. Sebastian Wisse, to whom the physical sciences owe so many interesting observations made during his long residence in Quito, had the boldness, in 1845, to pass several nights in a part of the crater of Rucu-Pichincha, where, towards sunrise, the thermometer fell 3°·6 below the freezing point, or to 28°·4. The crater is divided into two parts by a ridge of rock covered with vitrified scoriæ. The eastern part is more than a thousand feet lower than the western one and is now the especial seat of volcanic activity. There, a cone of eruption rises to a height of nearly 270 feet, and is surrounded by more than seventy burning fumaroles exhaling sulphureous vapours. ([333]) It was probably from this eastern circular

crater (which now at its least-heated places is covered with tufts of reed-like grasses, and of a Pourretia with leaves resembling those of bromelias), that the eruptions of burning scoriæ, pumice, and ashes from the volcano proceeded in 1539, 1560, 1566, 1577, 1580 and 1660. The city of Quito was then often veiled for days in thick darkness by the falling ashes.

Of this more rare, elongated form of volcanoes, we know, in the old world, Galungung, with a large crater, in the western part of Java ([334]), the doleritic mass of the Schiwelutsch in the Kamtschatka, a chain whose highest points attain 10,167 feet ([335]), and Hecla, which seen from the north-west, or in the direction normal to that of the principal longitudinal fissure over which it was upheaved, presents a broad mountain ridge having different small "horns" or summits. Since the most recent eruptions, in 1845 and 1846, which gave a stream of lava eight miles long and at some places two miles broad, comparable to the stream of lava from Etna in 1669, there are on the back of Hecla five caldron-shaped craters arranged in a row. As the principal fissure is directed N. 65° E., the volcano, as seen from Selsundfiall, *i.e.* from the south-west side, and therefore as a cross section, appears a pointed cone. ([336])

If the shapes of volcanoes differ so strikingly from each other, as Cotopaxi and Pichincha, without the emitted substances and the chemical processes of the profound interior being altered, the relative position of the cones of elevation is sometimes yet more singular. In Luzon, one of the Philippine Islands, the still active volcano of Taal, whose most destructive eruption took place in 1754, rises in the middle of a large lake in-

habited by crocodiles, called the Laguna de Bombon. The cone, which was ascended in Kotzebue's voyage of discovery, has a crater lake, out of which again rises a cone of eruption with a second crater. ([337]) This description recalls involuntarily the mention, in the journal of Hanno's voyage, of an island enclosing a small lake, in the middle of which a second island rises. Two such instances would seem to have been met with, one occurring in the Gulf of the Western Horn, and the other in the Bay of the Gorilla Apes on the west coast of Africa. ([338]) Descriptions so particular would tend to make one believe them based on actual observation of nature!

The least and the greatest height of points at which the volcanic activity of the interior of the earth manifests itself permanently at the surface, is a hypsometric consideration interesting to physical geography, — to which belong all facts relating to the reaction of the fluid interior of the planet against its surface. The measure of the upheaving force ([339]) is, indeed, manifested in the height of volcanic cones; but great caution is necessary before pronouncing any judgment as to the influence of relative height upon the frequency and strength of eruptions. Particular contrasts between very high and very low volcanoes, in frequency and strength of effects, can determine nothing; and of the several hundred active volcanoes supposed to exist on continents and islands, our knowledge is still so incomplete, that the only decisive method, that of mean values, cannot yet be regarded as applicable; and, even if such mean numbers could give us a definite result by assigning the approximate altitude at which eruptions

recur oftenest, there would still remain room for doubt how far the influence of height, or distance from the volcanic hearth, was modified by all the incalculable accidental circumstances, which may render the network of fissures more or less impeded, or more or less easily traversed. The phænomenon is then, in respect to causal connection, "indeterminate."

Keeping cautiously to the facts only, where the complexity of the phænomena, and the want of historical information respecting the number of eruptions in the course of centuries, do not yet permit us to arrive at laws, I will content myself, in regard to the comparative hypsometry of volcanoes, with giving a table of five groups, in which the different classes of elevation are represented by a small number of well-authenticated examples. I have included in these five groups only detached mountains having craters still burning, therefore, active volcanoes strictly so called, not unopened domes, as Chimborazo. All cones of eruption are excluded which are dependent on an adjacent volcano, or which, at a distance therefrom, as in the Island of Lancerote, and in the Arso at the Epomeo in Ischia, have not preserved any permanent communication between the interior and the atmosphere. According to the testimony of that most zealous investigator of all that belongs to Mount Etna, Sartorius von Waltershausen, that volcano is surrounded by nearly 700 greater and lesser cones of eruption. As the measured heights of all summits are taken in relation to the level of the sea (the present liquid surface of our planet), it is important here to remind the reader, that *island* volcanoes—of which some, as the Japanese volcano

Kosima ([340]), described by Horner and Tilesius, at the entrance of the Tsugar Straits, do not rise 1000 feet above the waters, while others, as the Peak of Teneriffe ([341]), are 12,000 feet above the sea — have been actually upheaved by the volcanic forces from a sea-bottom often above 21,000 feet, and sometimes even nearly 46,000 feet deep. It is also important to remark, in order to avoid erroneous inferences from the subjoined numerical relations, that if between volcanoes of the 1st and the 4th class, *i.e.* between volcanoes of 1000 and of 18,000 French feet (1066 and 19,184 English feet), the differences appear very considerable, yet the proportion between these numbers becomes greatly altered if (in conformity with Mitscherlich's experiments on the fusion-temperature of granite, and according to the not altogether probable hypothesis that the heat increases uniformly in arithmetical progression with increasing depth) we assume the upper limit of the molten interior of the earth to be about 121,500 feet below the present level of the sea. The differences of height between known volcanoes are, we may well believe, not considerable enough to authorise us to expect that the height of the highest should present any materially increased obstacle to the effects of the tension of elastic vapours (powerfully increased when pent up by the stoppage of volcanic fissures) in forcing lava and other dense substances up to the crater.

Hypsometrical Table of Volcanoes.

First group of volcanoes, from 700 to 4000 French feet (from 746 to 4263 English feet) *:—

The volcano of the Japanese island Kosima, south of Jezo: 746 feet, according to Horner.

The volcano of the Lipari Island, named "Volcano:" 1304 feet, according to Fr. Hoffmann. (342)

Gunung Api (signifying, in the Malay language, fire-mountain), the volcano of the island of Banda: 1948 feet.

The volcano of Izalco (343), in a state of almost constant eruption; first ascended in 1770; in the State of San Salvador, in Central America: 2132 feet, according to Squier.

Gunung Ringgit, the lowest volcano in Java: 2345 feet, according to Junghuhn. (344)

Stromboli: 2957 feet, according to Fr. Hoffmann.

Vesuvius, the Rocca del Palo, on the highest northern margin of the crater: the mean of my two barometric measurements (345), in 1805 and 1822, gives 3997 feet.

The volcano of Jorullo, which broke forth, in a high Mexican plain (346), on the 29th Sept. 1759: 4265 feet.

* It would have been easy, and might have appeared more simple, to have made the divisions of this table at 4,000, 8,000, 12,000, and 16,000 *English* feet; but this would have introduced confusion in the subsequent reasoning, for example, by throwing Etna and the Peak of Teneriffe into different groups.

Second group, from 4000 to 8000 French feet (4263 to 8526 English): —

Mont Pélé de la Martinique: 4706 feet? according to Dupuget.

Souffrière de la Guadeloupe: 4867 feet, according to Charles Deville.

Gunung Lamongan, in the eastern part of Java: 5339 feet, according to Junghuhn.

Gunung Tengger; of all the volcanoes of Java, that which has the largest crater (347): height of the cone of eruption, Bromo, 7546 feet, according to Junghuhn.

Volcano of Osorno in Chili: 7549 feet, according to Fitz Roy.

Volcano of the island Pico (348), one of the Azores: 7613 feet, according to Vidal.

The volcano of the Isle of Bourbon: 8001 feet, according to Berth.

Third group, from 8000 to 12,000 French feet (8526 to 12,789 English): —

The volcano of Awatscha (in the peninsula of Kamtschatka); not to be confounded (349) with the rather more northerly Strieloschnaia Sopka, which English sailors commonly call the volcano of Awatscha: 8910 feet, according to Erman.

Volcano of Antuco (350), or Antoïo (in Chili): 8918 feet, according to Domeyko.

Volcano of Fogo, one of the Cape de Verde Islands (351): 9152 feet, according to Charles Deville.

Volcano of Schiwelutsch, Kamtschatka: north-eastern summit, 10,549 feet, according to Erman. (352)

Etna [353]: according to Smyth, 10,871 feet.

Peak of Teneriffe: 12,158 feet, according to Charles Deville. [354]

Gunung Semeru; this volcano is the highest mountain in Java: 12,235 feet, according to Junghuhn's barometric measurement.

Mount Erebus, in S. lat. 77° 32′; the nearest known volcano to the south pole [355]: according to Sir James Clark Ross, 12,366 feet.

Volcano Argæus [356] in Cappadocia, now Erdschisch-Dagh, S.S.E. of Kaisarieh: 12,600 feet, according to Pierre von Tschichatscheff.

Fourth group, from 12,000 to 16,000 French feet (12,789 to 17,052 English): —

Volcano of Tuqueres [357] in the highlands of the Provincia de los Pastos: according to Boussingault, 12,821 feet.

Volcano of Pasto [358]: according to Boussingault, 13,450 feet.

Volcano Mauna Roa [359]: according to Wilkes, 13,758 feet.

Volcano of Cumbal [360] in the Provincia de los Pastos. 15,618 feet, according to Boussingault.

Volcano Kliutschewsk [361] (Kamtschatka): according to Erman, 15,763 feet.

Volcano Rucu-Pichincha: according to barometric measurements by Humboldt, 15,923 feet.

Volcano Tungurahua: according to a trigonometrical measurement by Humboldt [362], 16,491 feet.

Volcano of Puracé([363]) near Popayan: 17,006 feet, according to José Caldas.

Fifth group. From 16000 to above 20000 French feet (17,052 to above 21,315 English):—

Volcano Sangay, south-east of Quito: 17,124 feet according to Bouguer and La Condamine. ([364])

Volcano Popocatepetl([365]): according to a trigonometrical measurement by Humboldt, 17,726 feet.

Mount Elias ([366]) west coast of North America: according to the measurements of Quadra and Galeano, 17,851 feet.

Volcano of Orizaba ([367]) 17,879 feet, according to Ferrer.

Volcano of Tolima ([368]): according to a trigonometrical measurement by Humboldt, 18,129 feet.

Cotopaxi ([369]): 18,877 feet, according to Bouguer.

Volcano of Arequipa ([370]): according to a trigonometrical measurement by Dolley, 18,879? feet.

Volcano Sahama (in Bolivia) ([371]): according to Pentland, 22,349 feet.

The volcano with which the fifth group terminates is more than twice as high as Etna, and five and a half times as high as Vesuvius. The graduated scale of volcanoes which we have passed in review—beginning with the low Maars of the Eifel (mine-funnels, without external framework, which have thrown out balls of olivine surrounded by half-fused schistose fragments) and ending with the still active Sahama, more than 22,000 feet high—has taught us that there is no

necessary connection between the maximum of elevation and a less degree of volcanic activity, or the nature of the visible rock. Observations limited to particular countries might easily lead us into error in this respect. For example, in the part of Mexico which lies within the tropics, all the mountains which are covered with perpetual snow (therefore, the culminating points of the whole country) are volcanoes; and this is also for the most part the case in the Cordilleras of Quito, providing we permit ourselves to associate with the volcanoes trachytic domes not open at the summit (Chimborazo and Corazon): but on the other hand, in the eastern chain of the Andes of Bolivia, the greatest mountain heights are completely unvolcanic. The Nevados of Sorata (21,288 feet) and Illimani (21,148 feet) consist of graywacke slates, which have been broken through by masses of porphyry ([372]), in which (as still remaining evidences of the fact) fragments of slate are found enclosed. Also in the eastern Cordillera of Quito, south of the parallel of 1° 35′, the high snow-covered summits of Condorasto, Cuvillan, and the Collanes, which are opposite to the trachytic mountains, consist of mica slate and slaty quartz. According to what we now know (thanks to the meritorious labours of Brian Hodgson, Jacquemont, Joseph Dalton Hooker, Thomson, and Henry Strachey) of the mineralogical constitution of the greatest elevations in the Himalaya, it would appear that there also, what used to be called the primitive rocks — granite, gneiss, and mica slate — are the visible rocks, but not any trachytic formations. Pentland, in Bolivia, found fossil shells in the Silurian schists on the Nevado of Antacaua, 17,478 feet above

the sea, between La Paz and Potosi. The enormous height to which fossils found by Abich in Daghestan, and by myself in the Cordilleras of Peru (between Guambos and Montan), show the chalk formation to have been lifted, forcibly remind us that non-volcanic sedimentary strata, full of organic remains, not to be confounded with volcanic beds of tufa, show themselves in places where, for a great distance around, melaphyres, trachytes, dolerites, and other pyroxenic rocks, to which the upheaving impelling forces are attributed, remain concealed deep below. What vast tracts of the Cordilleras and of the country to the eastward may be explored without any visible trace of any granitic rock!

As I have already, more than once, remarked, the frequency of eruptions in a volcano appears to be dependent on varied and very complicated causes; no general law can be established respecting the ratio of absolute height to frequency and intensity of igneous action. If in one small group, the comparison of Stromboli, Vesuvius, and Etna, might mislead us to suppose that the number of eruptions is inversely proportional to the height of the volcano, we soon find other facts which are in direct contradiction to this supposition. Sartorius von Waltershausen, who has done so much for the knowledge of Etna, remarks that, taking the average of recent centuries, an eruption may be expected about every six years, whereas in Iceland (where, properly speaking, no part of the island can be said to be secure from destruction by subterranean igneous action), Hecla, which is 5755 feet lower than Etna, has, so far back as our knowledge extends, sent forth eruptions only every seventy or eighty years. (373) The Quito group of

volcanoes presents a far more striking case. The volcano of Sangay, 17,052 feet high, is much more active than the little volcano of Stromboli (2957 feet); of all known volcanoes it is the one which shows the greatest number of eruptions of far-shining fiery scoriæ, in short intervals of time. Instead of bewildering ourselves amidst hypotheses on the causal relations of inaccessible phænomena, we may here, in preference, pause to consider six points on the earth's surface, which are peculiarly important and instructive in the history of volcanic activity: — Stromboli; the Chimæra in Lycia; the ancient volcano of Masaya; the very recent one of Izalco; Fogo, in the Cape de Verde Islands; and the colossal Sangay.

The Chimæra in Lycia, and Stromboli, the ancient Strongyle, are the two igneous phænomena of volcanic activity, whose historically proved permanence reaches farthest back. The conical hill of Stromboli, a dolerite rock, is twice as high as the volcano in the island of Volcano (Hiera, Thermessa), whose last great eruption was in 1775. The uninterrupted activity of Stromboli was compared by Strabo and Pliny with that of Lipari, the ancient Meligunis; but "its flame" (*i. e.* its emitted scoriæ) is said to possess "with less heat, greater purity, and a stronger light." (374) The number and forms of the little fiery orifices are very variable. Spallanzani's representation of the crater-floor, which was long regarded as exaggerated, has been fully confirmed by an experienced geologist, Friedrich Hoffmann, and more recently by an acute physicist, A. de Quatrefages. One of the red-glowing fiery orifices has an opening of only 21 feet diameter: it resembles the shaft of an oven

or furnace; and looking down upon it at any time from the margin of the crater, one sees the fluid lava mounting and overflowing. The permanent eruptions of Stromboli still serve, as in ancient times, as a guide to mariners; and also, by the direction of the flame and of the ascending vapours, afford, as they did to the Greeks and Romans, uncertain prognostications as to weather. The various signs of a near change of wind are connected with the myth of Eolus's first residence at Strongyle, and still more with observations on the then vivid fire on Volcano (the "sacred isle of Hephæstos" — Vulcan), by Polybius, who shows a remarkably exact knowledge of the state of the crater. The frequency of the fiery appearances has in recent times shown some irregularity. The activity of Stromboli, as well as that of Etna, is, according to Sartorius von Waltershausen, greatest in November and the winter months. It is sometimes interrupted by pauses of repose; but these, as the experience of many centuries has shown, are of short duration.

The Chimæra in Lycia, which has been so excellently described by Admiral Beaufort, and of which I have already twice spoken, (375) is not a volcano, but a perpetual fire-fountain, or a spring of gas kept always in a state of ignition by the volcanic activity of the interior of the earth. It has been recently visited by a talented artist, Albert Berg, for the purpose of obtaining picturesque views of a locality famed from high antiquity (since the times of Ctesias and Scylax of Caryanda), and to collect specimens of the rocks from amidst which the flame of the Chimæra issues forth. The descriptions of Beaufort, Edward Forbes,

and Spratt, in the "Travels in Lycia," are perfectly confirmed. An eruptive mass of serpentine rock traverses the dense limestone, in a ravine which ascends from south-east to north-west. At the northern extremity of the ravine the serpentine is cut off, or perhaps only concealed, by a curved crest of calcareous rock. The specimens of serpentine brought home are partly green and fresh, and partly brown and weathered. In both, diallage is clearly recognisable.

The volcano of Masaya, (376) which was celebrated even at the beginning of the 16th century, and concerning which, under the name of the Infierno de Masaya, reports were made to the Emperor Charles V., is situated between the lakes of Nicaragua and Managua, south-west of the charming Indian village of Nindiri. For centuries it presented the same rare and curious phænomena as those described at the volcano of Stromboli. In looking down from the margin of the crater, the waves of fluid lava, as moved by the subterranean vapours, were seen to rise and fall in the red-glowing abyss. The Spanish historian Gonzalez Fernando de Oviedo first ascended Masaya in July 1529, and drew comparisons between it and Vesuvius, which he had previously visited (1501) in the suite of the Queen of Naples, as her *xefe de guarda-ropa*. The name "Masaya" belongs to the Chorotega language of Nicaragua, and signifies "burning mountain." This volcano, surrounded by an extensive lava-field (mal-pays), which it has probably formed, was then reckoned as belonging to the mountain-group of the "nine burning Maribios." "In its ordinary state," says Oviedo, "the surface of the lava, on which black scoriæ are floating, remains several hundred feet below

the margin of the crater; but sometimes, by a sudden vehement boiling up, it almost reaches the upper rim." The perpetual light seen from a distance is remarked by Oviedo (who expresses himself on the subject with great distinctness and sagacity) to have been caused, not by any real flame, ([377]) but by vapours illuminated from beneath. The light is said to have been so strong, that at a distance of more than three leagues, on the route from the volcano to Granada, the illumination of the country around almost equalled that of the full moon.

Eight years after Oviedo's visit, the volcano was ascended by the Dominican monk Fray Blas del Castillo, who entertained the foolish notion that the fluid lava in the crater was liquid gold, and associated himself with an equally covetous Franciscan monk of Flanders, Fray Juan de Gandavo, for obtaining it. These two men, availing themselves of the credulity of the Spanish settlers, set on foot a "company" who were to furnish the necessary funds, "they themselves, however," as Oviedo sarcastically remarks, "claiming exemption," as ecclesiastics, "from any pecuniary contribution." The account of the execution of this bold undertaking, given by Fray Blas himself in a report to the Bishop of Castilla del Oro, Thomas de Verlenga, has been only recently made known (1840) by the discovery of Oviedo's memoir on Nicaragua. Fray Blas del Castillo is the same person that is spoken of in the writings of Gomara, Benzoni, and Herrara, as Fray Blas del Inesta. He had once served on board a vessel as a sailor, and wished to imitate the method he had seen used by the inhabitants of the Canary Islands for gathering the Lichen Roccella

(which furnishes a dye-stuff), from the face of precipitous cliffs, suspending themselves for that purpose by ropes overhanging the sea. For some months various contrivances were tried with a crane and pulley for supporting a long beam over the abyss. The Dominican, with his head covered with an iron helmet, and a crucifix in his hand, and three other members of the association were let down, and remained for a whole night on a part of the solid crater floor, from whence they made vain attempts to fill earthen vessels, lowered in an iron caldron, with the supposed liquid gold. In order not to discourage the shareholders([378]), they agreed to say, when they were drawn up, that they had found great riches; and that "el Infierno de Masaya" would henceforth deserve to be called "el Paraiso de Masaya." The operation was subsequently repeated several times, until the governador of the neighbouring city of Granada, either suspecting the deceit or that the royal revenue would be defrauded, forbade "persons being let down by ropes into the crater." This was in the summer of 1538; but in 1551, Juan Alvarez, Dean of the Chapter of Leon, received from Madrid the very *naïve* permission "to open the volcano and take out the gold contained in it." Such were the popular beliefs in the 16th century; and even in our own times, in 1822, it was necessary that Monticelli and Covelli, at Naples, should demonstrate by chemical experiments that the ashes of Vesuvius, from the eruption of the 28th of December, did not contain any gold! ([379])

The volcano of Izalco, which is situated on the west coast of Central America, thirty-two miles north of San Salvador, and east of the harbour of Sonso-

nate, broke forth eleven years later than the volcano of Jorullo in the interior of Mexico. Both outbreaks took place in cultivated plains, and after several months of earthquakes and of subterranean "roarings" (bramidos). In the Llano de Izalco a conical hill was upheaved; and contemporaneously with its upheaval a stream of lava began to pour forth from its summit. This was on the 23rd of February 1770. It is still uncertain how much of its rapidly increasing height should be attributed to "upheaval of the ground," and how much to "accumulation" of erupted scoriæ, ashes, and masses of tufa; but it is certain that, instead of soon becoming extinct like Jorullo, the volcano of Izalco has continued, ever since its first appearance, in uninterrupted activity, and often serves as a lighthouse to mariners making the land in the Bay of Acajutla. Four eruptions of flame are reckoned to take place in an hour; and the great regularity of the phenomenon has astonished the few accurate observers who have witnessed it. ([380]) The strength of the eruptions varied, but not the time at which each took place. The height attained by the volcano of Izalco was estimated after the last great eruption, of 1825, at about 1600 feet, nearly equal to the height of Jorullo above the original cultivated plain from which it rose, but almost four times as great as the crater of elevation in the Phlegræan Fields, called the Monte Nuovo, to which Scacchi ([381]) assigns, by exact measurement, 431½ feet. The permanent activity of the volcano of Izalco, which was long regarded as a safety-valve for the country round San Salvador, did not, however, preserve the town from complete destruction on Easter night in 1854.

The one of the Cape de Verde Islands which rises between S. Iago and Brava had early received from the Portuguese the name of Ilha do Fogo, because, like Stromboli, it incessantly emitted fire; and it continued to do so from 1680 to 1713. After a long interval of repose, this volcano was rekindled in the summer of 1798, a short time after the last lateral outbreak of the Peak of Teneriffe in the crater of Chahorra, which crater was erroneously named, as if it had been a distinct mountain, the "Volcano of Chahorra."

The most active of all the volcanoes of South America, and indeed of all those which I have here enumerated, is Sangay; also called Volcan de Macas, because the remains of the ancient and, at the time of the Conquista, populous city of that name are situated only twenty-eight miles to the south of it, on the Rio Upano. This colossal mountain, 17,124 feet high, has been elevated on the eastern declivity of the Eastern Cordillera, between two systems of tributaries to the Great River of the Amazons, *i.e.* the river-systems of the Pastaza and of the Upano. The great and incomparable igneous phænomenon now presented by this volcano would appear to have only begun in 1728. In the measurement of an arc of the meridian by Bouguer and La Condamine (1738 to 1740), Sangay served them as a perpetual fire signal. ([382]) I myself heard its thunder for months in 1802 (particularly in the early morning) from Chillo near Quito, the pleasant country seat of the Marques de Selvalegre, as, half a century before, Don Jorge Juan had heard "the ronquidos del Sangay" from a point rather more to the north-east, near Pintac at the foot of Antisana. ([383]) In the years 1842 and 1843, when the

eruptions were combined with the greatest noise, the sound was heard distinctly, not merely in the harbour of Guayaquil, but also farther to the south, along the shores of the Pacific, as far as Payta and San Buenaventura; a distance about equal to that between Berlin and Basle, the Pyrenees and Fontainebleau, or London and Aberdeen. Although, since the beginning of the present century, the volcanoes of Mexico, New Granada, Quito, Bolivia, and Chili have been visited by geologists, yet, unfortunately, Sangay (which exceeds Tungurahua in height), owing to its solitary position remote from all routes of communication, has remained entirely neglected. It was not until December 1849, that an adventurous and highly informed traveller, Sebastian Wisse, who had resided five years among the Andes, ascended Sangay and almost reached the highest summit of the steep snow-covered cone; he determined chronometrically the exact intervals of the astonishingly frequent eruptions, and examined the composition of the trachyte which, limited to so restricted an area, breaks through the gneiss; 267 eruptions were counted in an hour, each lasting on an average 13″·4, ([384]) and — which is very remarkable — not accompanied by any sensible shaking of the cone of cinders. The erupted substances, veiled for the most part in much smoke (sometimes of a grey, and sometimes approaching to an orange colour), consisted chiefly of mingled black ashes and rapilli, but partly also of scoriæ, which rose perpendicularly and were globular, about 16 or 17 inches in diameter. In one of the strongest eruptions, Wisse counted from 50 to 60 glowing stones simultaneously erupted. Most of them fall back into the crater; sometimes they cover its upper margin, or

slide down a part of the cone, and are seen, at night, shining afar in the darkness: it was this probably which gave occasion to La Condamine's erroneous belief of "burning sulphur and asphalte being poured forth." The stones are thrown up individually and successively, so that some are falling back while others are rising. By exact measurement by time, the visible space of fall (reckoning therefore to the margin of the crater) was determined in the mean to be only 785 feet. At Etna, the stones thrown up reach, according to the measurements of Sartorius von Waltershausen and the astronomer Dr. Christian Peters, a height of 2660 feet above the crater. Gemellaro's estimations, during the Etna eruption of 1832, were even three times as high! The black ejected ashes form, on the slopes of Sangay and for twelve miles around, beds 300 or 400 feet thick. The colour of the ashes and rapilli gives to the upper portion of the volcano a peculiarly dismal and fearful aspect. Before closing this paragraph, I would once again call the reader's attention to the size of this great volcano (six times the height of Stromboli), because it militates strongly against the belief of the lower volcanoes having always the most frequent eruptions.

Even more important than the form and height of volcanoes is their grouping, because it leads us to the great geological phænomenon of *elevation over fissures.* Such groups of volcanoes, whether they have been elevated, according to Leopold von Buch, in lines, or simultaneously around a central volcano, indicate the parts of the earth's crust in which (whether it may have been from the lesser thickness of the rocky strata, or from their nature, or from their original fissuring) the tendency of the molten interior to break forth has

met with least resistance. Three degrees of latitude are included in the space in which the volcanic activity manifests itself fearfully in Etna, in the Æolian Isles, in Vesuvius, and the Phlegræan Fields, from Puteoli (Dicæarchia) to Cumæ and to the fire-vomiting Epopeus on Ischia, the Tyrrhenian Ape's Island Ænaria. Such a connection of analogous phenomena could not escape the notice of the Greeks. Strabo says, "The whole sea, beginning from Cumæ to Sicily, is traversed by fire, and has undoubtedly in its depths hollow passages communicating with each other and with the mainland. (385) Such an inflammable nature, as is described by all, shows itself not only in Etna, but also in the country around Dicæarchus and Neapolis, and around Baiæ and Pithecusæ." Hence arose the fable that Typhon lies under Sicily, and that, when he turns himself, flames and water burst forth, and sometimes even small islands and boiling water. "Often, between Strongyle and Lipara (in this wide sweep), flames are seen to issue from the surface of the sea, when the fire opens for itself a passage from the cavities in the depths, and violently forces its outward way." In Pindar (386), the body of Typhon is so vast, that "Sicily and the sea-surrounded heights above Cumæ (Phlegra, the 'field of burning') lie on the monster's shaggy breast."

Thus Typhon (the raging Enceladus) became in the Greek popular phantasy, the mythic designation of the unknown cause of volcanic phænomena, lying deeply buried in the bosom of the earth. By the situation and space assigned to his bulk, they indicated the boundaries and connected action of the particular vol-

canic system. In the richly imaginative geological picture of the interior of the earth in Plato's grand contemplation of Nature, in the Phædo (pp. 112—114), this connected action is, with still greater boldness, extended to all volcanic systems. In it the lava-streams draw their supplies from the Pyriphlegethon, where, "after it has often rolled round and round beneath the earth," it pours itself into Tartarus. Plato says expressly, that in "the fire-vomiting mountains, where such are found on the earth, small portions of the Pyriphlegethon are blown out." (*οὗτος δ' ἐστὶν ὃν ἐπονομάζουσι Πυριφλεγέθοντα, οὗ καὶ οἱ ῥύακες ἀποσπάσματα ἀναφυσῶσιν, ὅπῃ ἂν τύχωσι τῆς γῆς.*) The expression (page 113, B.), driving out with violence, may be understood to refer to the motive force of the previously enclosed and suddenly and forcibly escaping wind, on which subsequently Aristotle, in his "Meteorology," founded his whole theory of volcanic action.

In accordance with these views, thus common to ancient and modern times, the grouping of volcanoes is even more characteristically marked in linear arrangement, than when they are found around a single central volcano. It is most striking where it depends on the situation and extent of very long and mostly parallel fissures. Thus, in the New Continent, to cite only the most important series having the most numerous members, we find the linear groups of Central America and Mexico, of New Granada and Quito, of Peru, Bolivia, and Chili; and in the Old Continent the groups of the Sunda Isles (the southern Indian Archipelago, especially Java), the peninsula of Kamtschatka and its continuation in the Kurile Islands, and the Aleutian

Islands which form the southern boundary of the almost closed Behring's Sea. We will pause to consider some of these leading groups in more detail; particularities often lead, by their intercomparison, to the fundamental relations of phænomena.

The line of volcanoes of Central America (according to the older nomenclature, the volcanoes of Costa Rica, Nicaragua, San Salvador, and Guatemala) extends (from the volcano Turrialva near Cartago to that of Soconusco) over six degrees of latitude, 10° 9′ to 16° 2′ N., in a generally S. E. and N. W. line, and, with its few curves, has a length of 540 geographical miles, about equal to the distance between Vesuvius and Prague. The most near to each other (as if they had been upheaved upon a single fissure only sixty-four miles long), are the eight volcanoes which lie between the Laguna de Managua and the Bay of Fonseca, between the volcano of Momotombo, and that of Conseguina whose subterranean thunder in 1835 was heard in Jamaica and in the highlands of Bogota, resembling the fire of artillery. In Central America, and in the whole southern portion of the New Continent, or, to speak even more generally, from the Archipelago de los Chonos, in Chili, to the most northern volcanoes of Edgecombe, on the small island near Sitka, [387] and Mount Elias in Prince William's Sound—over a distance of 6400 geographical miles—the volcanic fissures have everywhere been opened on the western side, or nearest to the shore of the Pacific. At the point where the Central American line of volcanoes (in lat. $13\frac{1}{2}$°, north of the Gulf of Fonseca) enters the State of San Salvador, at the volcano of Conchagua, the directions, both of this line and of the western coast-line,

change simultaneously. The line of volcanoes now runs E.S.E.—W.N.W.; and farther on, where they are so near to each other that five, still in a state of greater or less activity, are found in the short course of 120 miles, the direction even becomes almost E.—W. This deflection corresponds to a great widening of the continent towards the east, in the peninsula of Honduras, where the coast-line turns as suddenly, and runs from Cape Gracias á Dios to the Gulf of Amatique for 300 miles due east and west, its direction having been before, for a similar distance, north and south. At the group of the high volcanoes of Guatemala, 14° 10′ N., the line resumes its earlier N. 45° W. bearing, and maintains the same to the Mexican frontier towards Chiapa and the isthmus of Huasacualco. North-west from the volcano of Soconusco to that of Turtla, there has not been found even an extinct cone of trachyte; mica slate and granite rich in quartz everywhere prevail.

The volcanoes of Central America do not crown the adjacent mountain-chains, but rise for the most part singly, and entirely detached from each other, along the foot of the chains. The greatest elevations are at the two extremities. At the southern end, in Costa Rica, from the summit Irasu (the volcano of Cartago) both oceans are visible, to which indeed, besides the height (11,079 feet), the more central position contributes. South-east of Cartago there are mountains between 11,000 and 12,000 feet high,—Chiriqui 11,262, and the Pico Blanco 11,737 feet. Nothing is known of the rocks of which they consist; probably they are unopened trachytic cones. Farther to the south-east, the mountains in Veragua sink to little more than 5000

and 6000 feet. This appears to be the mean height of the volcanoes of Nicaragua and San Salvador; but towards the north-western extremity of the whole line, not far from the new city of Guatemala, two volcanoes again rise to above 13,000 feet. The maxima therefore fall, according to my attempt at hypsometric classification of volcanoes, into the third group, like Etna and the Peak of Teneriffe; whereas the greater number of elevations, situated between the two extremities of the line, are scarcely 2000 feet higher than Vesuvius. The volcanoes of Mexico, New Granada, and Quito belong to the fifth group, and mostly exceed 16,000 French feet (17,052 English).

Although in Central America the continent, from the Isthmus of Panama, through Veragua, Costa Rica, and Nicaragua, to the parallel of $11\frac{1}{2}°$ N., widens considerably, yet, from the great area of the lake of Nicaragua, and the low level of its surface (less than 130 feet above either sea), [388] there is such a depression of the land that an overflowing current of air from the Caribbean Sea often passes across to the Pacific, causing those north-east storms, dangerous to navigation, which sometimes rage uninterruptedly for four or five days. These storms have the remarkable feature of being usually accompanied by an almost cloudless sky. They are termed "Papagayos," and have given this name to the part of the west coast of Nicaragua which is between Brito, or Cabo Desolado, and Punta S. Elena (from 11° 22′ to 10° 50′ N. lat.): it is called Golfo del Papagayo, and, south of the Puerto de San Juan del Sur, encloses the little bays of Salinas and S. Elena. In sailing from Guayaquil to Acapulco, I had an opportunity of observ-

ing the Papagayos for more than two entire days (9—11 March 1803) in all their strength and peculiarity, but a little more to the south, viz. in less than 9° 13′ N. The waves were higher than any that I had ever seen; and the constant visibility of the sun in the clearest blue sky made it possible to measure their height by altitudes of the sun taken on the crest of the wave, and in the trough of the sea, by a method which had not then been previously tried. All Spanish, English [389], and American navigators ascribe these storms in the Pacific to the north-east trade in the Atlantic.

In a new work [390] prepared with much pains, partly from already published, and partly from manuscript materials, on the "Reihen-Vulkane" of Central America, I have enumerated twenty-nine volcanoes whose former, or present, greater or less degree of activity may be safely affirmed. The natives give a number more than one third greater, adducing, in so doing, several ancient basins of eruption which may have been only lateral eruptions on the declivity of one and the same volcano. Among the isolated conical and bell-shaped mountains which are there called volcanoes, there may indeed be many which consist of trachyte or dolerite, but which have always remained "unopened" and have never shown any igneous activity since their upheaval. Eighteen may now be regarded as "burning;" of those which hav sent forth flames, scoriæ, and lava in the present century (1825, 1835, 1848, and 1850), seven; and in the latter part of the last century (1775 and 1799), two. [391] The absence of streams of lava in the great volcanoes of Quito has in modern times repeatedly given occasion to statements

implying a similar absence of lava in those of Central America. It is true, indeed, that in the majority of cases, as, for example, at the present time in the volcano of Izalco, eruptions of scoriæ and ashes are unaccompanied by streams of lava; but the descriptions given by eyewitnesses of lava-pouring eruptions in four volcanoes — Nindiri, el Nuevo, Conseguina, and San Miguel de Bosotlan—militate against the supposition above noticed.(392)

I have purposely dwelt at some length on the peculiarities of the situation and near vicinity to each other of the volcanoes of the Central American line, in the hope that some geologist, who has made himself thoroughly acquainted with the active European volcanoes, and the extinct ones of Auvergne or of the Vivarais or of the Eifel, and (which is of the greatest importance) who is competent to describe the mineralogical composition of the rocks according to the requirements of the present state of knowledge, might feel himself incited to visit so near and accessible a region. Much still remains to be done there, supposing the traveller to devote himself exclusively to geognostical researches and particularly to the mineralogical determination of the trachytes, dolerites, and melaphyres,—to the discrimination of the originally upheaved mass from the part which has been covered over by subsequent eruptions,—and to the discovery and recognition of actual narrow uninterrupted currents of lava, which are too often confounded with accumulations of erupted scoriæ. Conical or dome or bell-shaped mountains which have never been opened are to be most carefully distinguished from volcanoes which either now emit, or have at

any former period emitted scoriæ and lava, like Vesuvius and Etna, or scoriæ and ashes only, like Pichinca and Cotopaxi. I do not know anything which holds out a better promise of a brilliant advance in our knowledge of volcanic activity, in which sufficiently varied observations extending over large and connected continental spaces are still greatly wanting. And further, supposing collections of rock-specimens to be obtained and brought home from several isolated true volcanoes, and from unopened trachytic cones, and also from the non-volcanic masses which have been broken through by them, the chemical analysis to which the specimens would be submitted, and the chemico-geological inferences which would be drawn from the analysis, would open a no less wide and fruitful field. Central America and Java have both the undeniable advantage over Mexico, Quito, and Chili, of offering the most varied and the most crowded examples of "scaffoldings" in which volcanic activity is displayed over large areas.

At the point, in lat. 16° 2′ N., where at the boundary of Chiapa the very characteristic series of the Central American volcanoes terminates in the volcano of Soconusco, a wholly different system of volcanoes, the Mexican one, begins. The isthmus of Huasacualco and Tehuantepec, so important for future commerce with the coasts of the Pacific, as well as the more north-westerly State of Oaxaca, is entirely without volcanoes, and perhaps also without unopened trachytic cones. It is not until after a distance of 160 miles from Soconusco, that the small volcano of Turtla, in lat. 18° 28′, rises on the coast of Alvarado. Situated on the eastern declivity of the Sierra de San Martin, it had a great eruption of flames

and ashes on March 2, 1793. In consequence of having made exact determinations of the latitudes and longitudes of the giant Snowy Mountains and volcanoes in the interior of Mexico, and while entering the culminating points on my large map of New Spain after my return to Europe, I was led to the exceedingly remarkable result, that there is there a parallel of volcanoes and of culminating points running from sea to sea, and deviating only a few minutes on either side of the parallel of 19°. The only volcanoes, and at the same time the only summits covered with perpetual snow,—therefore the only mountains exceeding 12,000 feet in the country,—the volcanoes of Orizaba, Popocatepetl, Toluca, and Colima, lie between the parallels of latitude of 18° 59′ and 19° 20′, and mark at the same time "the direction of a fissure of volcanic activity" 360 miles in length. (393) In the same east and west line (in lat. 19° 9′), intermediate between the volcanoes of Toluca and Colima, distant 116 miles from one, and 128 miles from the other, in a wide plain 2583 feet high, the new volcano of Jorullo (4265 feet) was upheaved on the 14th of September 1759. The locality of this event, viewed in relation to the situation of the other Mexican volcanoes,—and the circumstance that the east and west fissure I have just spoken of intersects at almost right angles the south south-east and north north-west direction of the great chain of mountains,—are geological phenomena no less important than are the distance from the sea of the point at which Jorullo has been elevated, and the evidences of its upheaval which I have represented in detail graphically, viz. the countless vapour-exhaling hornitos which surround the volcano, and the

pieces of granite which, in a district otherwise entirely devoid of granite for a great distance, I found imbedded in the lava which had poured forth from the principal volcano of Jorullo.

The following table contains the latitudes and altitudes of the series of Mexican volcanoes which have been elevated over a fissure running from sea to sea and crossing the fissure of elevation of the great mountain-chain.

Series from E. to W.	Geogr. Latitude.	Height above the Sea.
Volcano of Orizaba . . .	19° 2′ 17″	17,879 feet.
Nevado Iztaccihuatl . . .	19 10 3	15,705
Volcano Popocatepetl . .	18 59 47	17,726
Volcano of Toluca . . .	19 11 33	15,168
Volcano of Jorullo . . .	19 9 0	4,265
Volcano of Colima . . .	19 20 0	13,003

The westward prolongation of this parallel of volcanic activity in the tropical zone in Mexico conducts, at a distance of 440 miles from the coast, to a group of islands in the Pacific called Revillagigedo, in the vicinity of which Collnet has seen pumice floating, and perhaps, yet farther, to the great volcano of Mouna Roa (19° 28′ lat.) 3360 miles distant, without the upheaval of any intervening islands.

The linear group of Quito and New Granada comprises a volcanic zone which extends from 2° S. to nearly 5° N. latitude. The extremities of the area, in which the reaction of the earth's interior against the surface now manifests itself, are the uninterruptedly active volcano Sangay, and the Paramo and Volcan de

Ruiz, which became again active in 1829, and from which Carl Degenhardt saw smoke issue in 1831 and 1833, he being, on the first occasion, at the Mina de Santana in the province of Mariquita, and on the second at Mormato. Proceeding southwards from Ruiz, the next most remarkable traces of great phænomena of eruption are shown by the truncated cone of the volcano of Tolima (18,120 feet), celebrated on account of its devastating eruption of the 12th of March 1595; the volcanoes of Purace (17,006 feet) and Sotara, near Popayan; of Pasto (13,450 feet), near the town of the same name; of the Monte de Azufre (12,821 feet), near Tuquerres; of Cumbal (15,618 feet); and of Chiles in the Provincia de los Pastos. Then follow the historically more celebrated volcanoes of what is more strictly called the Highland of Quito, south of the equator, of which four, viz. Pichincha, Cotopaxi, Tungurahua, and Sangay, may certainly be regarded as still active. If, as will be presently more fully shown, to the north of the mountain-knot of Robles, near Popayan, where the great chain of the Andes forks into three, it is only in the middle cordillera, and not in the western one which is nearest to the sea, that volcanic activity shows itself, on the other hand, to the south of the said knot, where the Andes form only two parallel chains, being those so often mentioned in the writings of Bouguer and La Condamine, the distribution is so equal that the four volcanoes of Pastos, as well as Cotocachi, Pichincha, Iliniza, Carguairare, and Yana-Urcu at the foot of Chimborazo, have broken forth on the western cordillera; and Imbabura, Cayambe, Antisana, Cotopaxi, Tungurahua (over against Chimborazo, yet near the

middle of the narrow high plain), the Altar de los Collanes (Capac-Urcu), and Sangay on the eastern one. If we embrace the whole northernmost group of South American volcanoes in one view, the opinion, often expressed in Quito and in some measure supported by historic accounts, of a migration of the greater intensity of volcanic activity to the southward, will seem to acquire some degree of probability. It is true, on the other hand, that in the south, by the side of the well nigh incessantly active colossal Sangay, we find the ruins of the "prince of mountains" Capac-Urcu, said to have surpassed Chimborazo in height, but which in the latter part of the fifteenth century (fourteen years before the conquest of Quito by the son of the Inca Tupac Yupanqui) fell in, became extinct, and has not since been rekindled.

The area not covered by groups of volcanoes in the Andes, is far greater than is commonly supposed. In the northern part of South America, from the Volcan de Ruiz and the cone of Tolima, the two northernmost volcanoes of the New Granada and Quito series, to beyond the Isthmus of Panama, about Costa Rica, where the Central American series begins, there extends a region of more than 600 geographical miles in length, which is, indeed, often powerfully agitated by earthquakes, and which contains flame-emitting salses, but in which true volcanic eruptions are not known. On the south, a still longer tract in which there are no volcanoes extends nearly 1000 miles, from Sangay, the southern extremity of the New Granada and Quito group, to Chacani near Arequipa, the commencement of the Peru and Bolivia series of volcanoes. So compli-

cated and so diverse must have been, within the same chain of mountains, the circumstances and relations on which the formation of permanently open fissures, and unobstructed communication between the molten interior and the atmosphere, depend. Between the groups of trachytic and doleritic rocks through which the volcanic forces become active, there intervene somewhat shorter tracts, in which the prevalent rocks are granite, syenite, mica schists, clay slates, quartzose porphyry, siliceous conglomerates, and calcareous rocks, of which last a considerable portion (according to Von Buch's skilful examination of the organic remains brought home by Degenhardt and myself) belong to chalk formations. As I have elsewhere remarked, the gradually increasing frequency of rocks containing labradorite, pyroxene, and oligoclase announces to the attentive traveller that he is passing from what had so far been a distinct zone, non-volcanic and often rich in silver found in porphyry without quartz and full of vitreous feldspar, into volcanic regions still in free communication with the interior of the earth.

The more exact knowledge which has been recently acquired of the position and boundaries of the five groups of volcanoes (*i. e.* the groups of Anahuac or tropical Mexico; Central America; New Granada and Quito; Peru and Bolivia; and of Chili) teaches us that in the portion of the Cordilleras which extends from $19\frac{1}{4}°$ north to 46° south latitude, making, with the curves occasioned by variations in the direction of the axis, a length of about 5000 geographical miles, very little more than the half (394) has volcanoes. If we examine the distribution of the non-volcanic spaces, we

find that the maximum interval is between the third and fourth of the aforesaid five groups, *i. e.* between the groups of Quito and Peru (fully 960 miles), while the least interval is between the first and second group, those of Mexico and Central America. The four intervals between the five groups are respectively 300, 630, 960, and 540 geographical miles. The great distance between the southernmost volcano of Quito and the northernmost of Peru occasions, at the first moment, the more surprise from the old custom of calling the measurement made on the highlands of Quito "the *Peruvian* Arc." It is only the smaller and southern portion of the chain of the Andes of Peru that is volcanic. According to lists which I have prepared after a careful discussion of the most recent data, the following is a general tabular view of the number of volcanoes in each group.

Names of the five linear Groups of American Volcanoes between 19° 25′ N. and 46° 8′ S. Latitude.	Number of Volcanoes in each Group.	Number of Volcanoes considered to be still active.
Mexican Group (395)	6	4
Central American Group (396) . . .	29	18
New Granada and Quito Groups (397) .	18	10
Peruvian and Bolivian Group (398) . .	14	3
Chilian Group (399)	24	13

According to this estimate, the total number of volcanoes in the five American groups is ninety-one, of which fifty-six belong to the South American continent. I reckon as volcanoes, in addition to those which are still burning and active, mountains from which eruptions are known to have taken place within historic times, and also mountains which by their structure and by the

presence of craters of elevation and eruption, of lavas, scoriæ, pumice, and obsidians, are characterised as volcanoes once active, but which had become extinct prior to traditional or historic evidence. Unopened trachytic cones and domes, or unopened long trachytic ridges, as Chimborazo and Iztaccihuatl are excluded. Von Buch, Charles Darwin, and Friedrich Naumann employ the word volcano with a similar limitation. I term "still active volcanoes" those which, when viewed in close proximity, still show signs of activity in a greater or less degree, and of which some have also had in recent times great and well-attested eruptions. I have purposely said "when viewed in close proximity," as this last is a very important condition; for many volcanoes have had their still-subsisting activity denied because, when viewed from the plain, the thin vapours which at a great height rise out of the crater are not seen. Thus, at the time of my American journey, it was even denied that Pichincha and the great volcano of Mexico, Popocatepetl, were still burning! although an enterprising traveller, Sebastian Wisse ([400]), counted in the crater of Pichincha, around the great cone of eruption, seventy still burning openings or "fumaroles," and, being engaged in measuring a base-line at the foot of Popocatepetl, in the Malpais del Llano de Tetimpa, I myself witnessed a very distinct eruption of ashes from that volcano. ([401])

In the New Granada and Quito line, about twice the length of the chain of the Pyrenees, and in which ten out of 18 volcanoes are still burning, we may point out four smaller groups or subdivisions. Proceeding from north to south, these are, the Paramo de Ruiz and the

adjacent volcano of Tolima (4° 55′ N. lat., according to Acosta); Purace and Sotara near Popayan (N. $2\frac{1}{4}$°); the Volcanes de Pasto, Tuquerres, and Cumbal (N. 2° 20′ to 0° 50′); and the series of volcanoes from Pichincha near Quito to the uninterruptedly active Sangay (from the equator to 2° S.). This last-named subdivision of the entire group is not particularly distinguished among the volcanoes of the New World, either by its great length or by the number it comprises; nor does it, as we now know, contain the highest summit: for Aconcagua in Chili (S. lat. 32° 39′), 23,003 feet high according to Kellett, 23,909 feet according to Fitz Roy and Pentland, as well as the Nevados of Sahama (22,349 feet), Parinacota (22,029 feet), Gualateiri (21,959 feet), and Pomarape (21,699 feet), all between 18° 7′ and 18° 25′ S. latitude, are all believed to be higher than Chimborazo (21,422 feet). Yet it is the volcanoes of Quito which, among all the volcanoes of the new continent, enjoy the most wide-spread renown; for it is to this part of the chain of the Andes, and to these highlands of Quito, that the remembrance of arduous labours for important objects in astronomical, geodesical, optical, and barometrical operations, attaches itself, in connection with the brilliant names of Bouguer and La Condamine. Where intellectual associations prevail, where a multitude of ideas have been awakened which have led simultaneously to the enlargement of several sciences, fame remains long attached to the locality. Thus it has been in the Swiss Alps with Mont Blanc, not on account of its height, in which respect it surpasses Monte Rosa only by 557 feet, nor on account of dangers overcome in its ascent, but by reason of the value, number, and

variety of the physical and geological views which shed a lustre around the name of de Saussure, and around the scenes of his untiring labours. External nature appears to us clothed with the most grandeur where her direct visible image is blended with its reflection from the intellectual mirror of the human mind.

The Peruvian and Bolivian series, also belonging wholly to the equinoctial zone, and, according to Pentland, not covered with perpetual snow until the height of nearly 17,000 feet is reached (Darwin, Journal, 1845, p. 244), attains its maximum elevation (22,350 feet) in about the middle of its length, in the Sahama group, between 18° 7′ and 18° 25′ S. lat. At Arica, there takes place a remarkable rounded inflection of the coast-line, which corresponds to a sudden alteration in the direction of the axes both of the chain of the Andes and of the western volcanic line. From thence southwards the direction of the coast, and at the same time of the volcanic fissure, is no longer from N.W. to S.E., but from north to south, which direction it maintains until near the western entrance of the Straits of Magellan, over a distance of more than two thousand geographical miles. A map of the "Verzweigungen und Bergknoten der Andeskette," which I published in 1831, shows many similar correspondences between the outline of the continent and the course of the Cordilleras near or distant. Thus, between the capes Aguja and San Lorenzo (5½° to 1° S. lat.), both the shore of the Pacific and the Cordilleras run from south to north, after having so long run from south-east to north-west between the parallels of Arica and Caxamarca; and thus, from the mountain-node of Imbaburu near Quito to that of De

los Robles ([402]) near Popayan, the coast-line and the Cordilleras agree in a course which is even from S.W. to N.E. It seems difficult to determine anything as to the geological causal connection in this frequently manifested accordance between the outlines of continents and the direction of adjacent mountain-chains (South America, Alleghanys, Norway, Apennines).

Although at present in the volcanic series of Bolivia and Chili, it is the *western* branch of the Andes, or that nearest to the Pacific, which shows most traces of still-subsisting volcanic activity, yet a very experienced observer, Pentland, has also discovered at the foot of the *eastern* chain, more than 180 geographical miles from the sea, a perfectly preserved but extinct crater with unmistakable streams of lava. This crater is at the summit of a conical mountain near San Pedro de Cacha, in the valley of Yucay 12,000 feet high (lat. 14° 8′, long. 71° 20′); south-east of Cuzco, where the eastern snowy range of Apolobamba, Caxabaya, and Vilcanoto stretches from S.E. to N.W This noteworthy point ([403]) is marked by the ruins of a celebrated temple of the Inca Viracocha. The distance of this former lava-yielding volcano from the sea is much greater than that of Sangay (which also belongs to an eastern cordillera), and greater than that of Orizaba, or of Jorullo.

An interval of 540 miles without volcanoes divides the volcanic series of Peru and Bolivia from that of Chili; this is the distance of the eruption in the desert of Atacama from the volcano of Coquimbo. As already remarked, 2° 34′ farther to the south the Chilian group of volcanoes reaches its maximum of elevation in Aconcagua, 23,003 feet high, which is also, according to

our present information, the maximum elevation of all the mountains of the new continent. The mean height of the Sahama group is 22,008 feet, or 586 higher than Chimborazo. Then follow in rapidly diminishing elevation Cotopaxi, Arequipa (?), and Tolima, between 18,877 and 18,129 feet. I give unaltered, in what look like very exact numbers, the results of measurements which, unfortunately, are necessarily compounded of trigonometric and barometric determinations; but I do so with the view of inciting others to repetition and correction. Of the Chilian group of volcanoes a few only, out of the number of 24 mentioned in the table, have had their elevations determined; and these are mostly only the southernmost, or those between the parallels of 37° 20′ and 43° 40′, from Antuco to Yantales, and which are also the lowest, having only the inconsiderable elevation of from 6000 to a little more than 8000 feet. In Tierra del Fuego the summit of Sarmiento, covered with perpetual snow, rises only (according to Fitz Roy) to the height of 6821 feet. From the volcano of Coquimbo to the volcano of San Clemente, the distance is 968 miles.

For the continual activity of several of the Chilian volcanoes we have the important testimony of Darwin ([404]), who regards Osorno, Corcovado, and Acongagua as decidedly still active, and the evidence of Meyen, Pöppig, and Gay, who ascended Maipu, Antuco, and Peteroa; of Domeyko, the astronomer Gilliss, and Major Philippi. The number of still-burning craters may be taken at thirteen — only five less than in the Central American group.

We now turn from these American continental

volcanic groups to the old continent, where, on the contrary, we find the greater number of crowded groups of volcanoes not on the mainland, but on islands. Thus, most of the European volcanoes are in the Mediterranean, and indeed (including the great and repeatedly active crater between Thera, Therasia, and Aspronise) in the Tyrrhenian and Ægean portions of that sea; and in Asia the mightiest volcanoes are to the south and east of the continent, in the greater and lesser Sunda Islands, the Moluccas and the Philippines, in the islands of Japan, and the Kurile and Aleutian archipelagos.

In no other part of the earth's surface are there such frequent and such fresh traces of active communication between the interior and the exterior of our planet, as in that comprised between the parallels of 10° S. and 14° N. latitude, and the meridians of the south point of Malacca and of the west point of the Papua peninsula of New Guinea. The area of this volcanic archipelago, washed by the Sunda, Banda, Solo, and Mindoro seas, scarcely equals that of Switzerland. The single island of Java contains at present a greater number of still-burning volcanoes than does the whole southern half of America, although it is only 544 geographical miles long, or one seventh of the length of South America. A new and long-looked-for light on the geological constitution of Java (after the earlier and very incomplete though meritorious labours of Horsfield, Raffles, and Reinwardt) has been recently afforded by a courageous, accomplished, and unweariedly active explorer of nature, Franz Junghuhn. After a residence of more than twelve years in Java he has comprised the whole natural history of that island in an instructive

work entitled, "Java, seine Gestalt und Pflanzendecke und innere Bauart." Above 400 heights were measured barometrically with great care; the volcanic, conical, and bell-shaped mountains, 45 in number, were all drawn in profile, and, with the exception of three (405), were all ascended by Junghuhn. Above half (at least 28) were recognised as still burning and active; their remarkable and very various forms have been most clearly described, and the history of their eruptions, as far as was possible, investigated. No less important than the volcanic phænomena of Java, are its sedimentary rocks of tertiary formation, which previously to the above-mentioned work were wholly unknown to us, although they cover three fifths of the entire area of the island, especially its southern portion. In many parts of Java there are found, as remains of former extensive forests, pieces, from three to seven feet long, of silicified trunks of trees exclusively dicotyledonous. For a land in which palms and tree ferns now grow in abundance, this is the more remarkable, because in the miocene tertiary rocks (the brown coal) of Europe, where arborescent monocotyledons do not now grow, fossil palms are often found. (406) By diligently forming a collection of impressions of leaves and of fossilised woods, Junghuhn has provided materials which, being ably examined and worked up by Göppert into an "ancient flora" of Java, have given us the first example of a fossil flora from a purely tropical region.

The volcanoes of Java are far inferior in height to those which we have been speaking of in America, the Chilian, Bolivian, and Peruvian groups, and even to the less lofty groups of Quito and New Granada, and of tropical Mexico (23,000, 21,000, and 18,000 feet),—the highest

of the South American volcanoes being almost the height of Etna above the highest volcanoes in Sumatra and Java. In the latter island, the still-burning Gunung Semeru is the culminating point of the whole Javanese series. Junghuhn ascended it in September 1844; the mean of his barometric measurements gave 12,235 feet above the sea, being 1748 feet higher than Etna. At night the thermometer sank to 43° Fahr. The more ancient Sanscrit name of Gunung Semeru was Mahâ Merû ("the great Meru"), recalling the Indian Mount Meru, which, according to the Mahabharata was the mythic seat of Brahma, Vishnu, and the seven Devarshi.([407]) It is remarkable that, as the natives of the high plain of Quito had guessed antecedently to any measurement that the Chimborazo surpassed in height all the other snowy mountains in their country, so also the Javanese knew the sacred mount Mahâ Merû, but a little distant from Gunung Ardjuno (11,030 feet high), to be the loftiest mountain in Java, although, from the less height of their mountains, they had not the aid to the judgment afforded by the inferior limit of perpetual snow, or of a temporary snow-shower.([408]) Next to Gunung Semeru, which, as we have seen, is a little above 12,000 English feet high, come four other volcanoes of from 10,727 to 11,116 English feet. These are (in descending series) Gunung Slamat([409]) or Mountain of Tegal (11,116 feet), G. Ardjuno (11,030), G. Sumbing (11,028), and G. Lavu (10,727). The heights of seven other Javanese volcanoes fall between 9000 and 10,000 French feet (9591 and 10,657 English). These results are the more remarkable, as it was previously supposed that no mountain on the island exceeded 6000 French feet.([410]) Of the five groups of North and South Ame-

rican volcanoes, that of Guatemala (Central America) is the only one which in *mean* height is exceeded by the Java group. Although the Volcan de Fuego near Old Guatemala is, according to Poggendorff's calculation, 13,109 English feet, or 874 feet higher than Gunung Semeru, yet the rest of the Central American volcanic series only range between 5000 and 7000 French feet, instead of, as in Java, between 7000 and 10,000 feet. The most lofty Asiatic volcano is to be found, however, not in the islands, but on the continent; for in the peninsula of Kamtschatka the volcano of Kliutschewsk rises to the height of 15,763 feet, or almost to that of Rucu-Pichincha in the Cordilleras of Quito. The well-filled volcanic range of Java, comprising more than 45 volcanoes, has its principal axis (411) in a W.N.W. and E.S.E. direction (more exactly, W. 12° N.), being parallel, not to the longitudinal axis of Java itself, but to the volcanic series in the eastern part of Sumatra.

The generality of direction in volcanic chains by no means excludes the phænomenon to which attention has been recently called in the great chain of the Himalayan mountains, *i. e.* that three or four single lofty summits may be so arranged as to constitute a short partial chain, whose axis may form an oblique angle with the principal axis of the entire chain. This fissure-phenomenon, which has been observed, and in part put forward, by Hodgson, Joseph Hooker, and Strachey, is of great interest. (412) The short axes of secondary fissures encounter the greater one, sometimes at almost a right angle; and even in volcanic chains, the very highest summits are often a little removed from the principal axis. In the Javanese as in most volcanic series, no de-

terminate relation is observed between the height of the mountain and the magnitude of the crater at the summit. The two largest craters belong to Gunung Tengger and Gunung Raon. The first of these is a mountain of the third class, only 8700 feet high. Its circular crater is about 3½ miles in diameter. The level floor of the crater is 1865 feet below the highest part of the surrounding escarpment, and consists of a smooth bed of sand or pulverised rapilli, out of which fragments of scoriaceous lava project here and there. Even the enormous crater of Kirauea in Hawaii, which is filled with glowing lava, is inferior in size (according to the exact trigonometrical survey of Captain Wilkes and the excellent observations of Dana) to the crater of Gunung Tengger. In the middle of the latter there rise four small cones of eruption, or, more strictly speaking, four ridge-encircled orifices, terminating in deep funnel-shaped hollows, of which one only, Bromo (the mythic name Brahma, a word which in the Kawi has the signification of "fire," which does not appear in the Sanscrit), is now not burning. Bromo presents the remarkable phenomenon of having had a lake formed in its funnel from 1838 to 1842, which Junghuhn has shown owed its origin to the access of atmospheric waters, warmed and acidified by the infiltration of sulphuric vapours. ([413]) Next to Gunung Tengger, Gunung Raon has the largest crater, though its diameter is only half as great. The view into it is awfully grand; it is at least 2400 feet deep; and yet this remarkable volcano (10,180 feet high, and which has been ascended and most carefully described by Junghuhn) ([414]) is not even named in Raffles's meritorious chart.

The volcanoes of Java, like most of the linear groups of volcanoes, present the important phænomenon, that simultaneity of eruption is much more rarely observed in cones adjacent to each other than in those which are far apart. When, in the night of the 11th of August 1772, the volcano Gunung Pepandajan (7034 feet high) broke out into the most destructive eruption with which the island of Java has ever been visited within historic times, in the same night (11th to 12th of August) two other volcanoes, G. Tjerimai and G. Slamat, which are situated respectively 184 and 352 geographical miles in a direct line from G. Pepandajan ([415]), also became ignited. Admitting the whole series of volcanoes to be over one and the same hearth, yet assuredly the network through which they communicate is so complicated, that the obstruction of ancient channels of vapour, or, in the course of centuries, the temporary opening of new ones, render conceivable a simultaneous outbreak at very distant points. I may here recall the circumstance of the sudden disappearance of the column of smoke from the volcano of Pasto, on the morning of the 4th of February 1797, when the dreadful earthquake of Riobamba shook the high plain of Quito between Tungurahua and Cotopaxi. ([416])

The volcanoes of Java are described as having generally a *ribbed* character, to which I have never seen anything similar in the Canaries, in Mexico, or in the Cordilleras of Quito. The traveller already alluded to, to whom we owe such excellent observations on the structure of volcanoes, the geography of plants, and the psychrometric relations of humidity in Java, has described this phænomenon with such remarkable clear-

ness, that, with the view of inciting others to new investigations, I think it desirable to call attention to this feature. Junghuhn says, "Although the face of a conical volcano 11,000 feet high, Gunung Sumbing, seen from some distance appears like an uninterruptedly smooth incline, yet on a nearer view it is found to consist of separate long narrow ridges or ribs, which become more and more divided, and wider, in descending. They proceed from the summit, and still more frequently from a height of a few hundred feet below the summit, to the foot of the mountain, diverging on all sides like the ribs of an umbrella." These long ridges or ribs have sometimes for a short distance a winding course; they are all divided from each other by intervening clefts 300 or 400 feet deep, which also widen out in descending. These radiated furrowings of the surface are found "on the sides of all the volcanoes in Java, but with considerable differences in regard to their mean depth and to the distance of their upper commencement from the margins of the craters or the unopened summits of the different mountains. Gunung Sumbing, 11,030 feet high, is one of those which show the finest and most regularly formed ribs, and with the greatest distinctness, as the mountain is without forest trees and is covered with grass." According to the measurements given by Junghuhn ([417]), the subdivision of the ribs increases with the decreasing angle of inclination. Thus, in G. Sumbing, above the zone of 9000 French feet there are only about 10 such ribs; at 8500 Fr. feet there are 32; at 5500 Fr. feet, 72; and at 3000 Fr. feet (3197 English), above 95;— the angle of inclination decreasing at the same time

successively from 37° to 25° and 10½°. The ribs of the volcano G. Tengger (8700 feet) are almost as regular; those of G. Ringgit have been in a great degree covered over and destroyed by the devastating eruptions which have taken place since 1586.(418) The origin of these very peculiar longitudinal ribs and of the intervening clefts, of which drawings are given, are ascribed to "erosion by torrents."

The mean quantity of meteoric water in this tropical region is indeed much greater than in the temperate zone: the rain often falls in floods resembling water-spouts; and although on the whole the quantity of moisture diminishes in ascending higher in the atmosphere, yet on the other hand great conical mountains are powerful attracters of clouds, and, as I have shown elsewhere, volcanic eruptions have a specific action in exciting tempests. Phenomena in some degree analogous are, indeed, presented by the clefts and valleys, called barrancos, in the volcanoes of the Canaries and of the Cordilleras of South America, described by Von Buch (419) and myself, which are important to the geological traveller in giving him access to the interior of the mountain, and sometimes even conducting him near to the highest summit and to the escarpment surrounding a crater of elevation; but although the barrancos at times form channels through which the meteoric waters are carried off, yet their first origin is not to be ascribed to such waters.(420) It is probable that fissures resulting from the folding of the soft upheaved and only later hardened trachytic masses preceded any effects of erosion by the action of the water. But in the deep barrancos on the declivities of domes or conical moun-

tains in the volcanic district visited by me, "*en las faldas* de los Cerros barrancosos," there were no of the regularity and radiating arrangement which Junghuhn has made known to us in the singularly formed volcanoes of Java. (421) Some analogy thereto may perhaps be traced in the phenomenon to which Von Buch and the ingenious observer of volcanoes Poulet Scrope had already called attention, viz., the circumstance that great fissures almost always open in the normal direction of the declivity, radiating (but without ramification) from the centre of the mountain, not transversely to it, either at a right or at an oblique angle.

The belief in the entire absence of streams of lava in the Javanese volcanoes (422), to which Leopold von Buch was inclined as the result of the experience of the meritorious Reinwardt, has been rendered more than doubtful by recent observations. Junghuhn does, indeed, remark that "the great volcano Gunung Merapi, within the historic period of its eruptions, has not poured forth any compact, *connected* streams of lava, but has only ejected lava fragments or *unconnected* pieces of rock, although, for nine months of the year 1837, lines of fire were nightly seen descending the slope of the cone of eruption." (423 But the same traveller has described circumstantially and distinctly three black basaltic lava-streams on three volcanoes — G. Tengger, G. Idjen, and Slamat. (424) On the last-named volcano the lava-stream, after giving occasion to a waterfall, is prolonged to the tertiary rocks. (425) Junghuhn, in describing the eruption of G. Lamongan(426), July 1838, distinguishes with great accuracy between such true out-

pourings of lava, forming connected masses, and what he terms a stream of stones, consisting of glowing fragments, for the most part angular, emitted in quick succession: "There was heard the crashing sound of the hurled-up stones falling on the declivity and rolling down, looking like points of fire, following each other either in line or without order." I desire to fix attention on the very different modes in which the appearance of fire on the slope of a volcano may be produced, because in the discussion on the maximum angle of fall of streams of lava, streams of glowing stones or fragments of rock (masses of scoriæ) have sometimes been confounded with continuous lava-currents.

As much has recently been said respecting the rarity, or supposed entire absence, of lava-streams in Java—a problem important in relation to the internal constitution of volcanoes, and which I venture to add has not been treated with sufficient earnestness,—the present appears to me a suitable opportunity for considering the question in a more general point of view. Although it is very probable that in a group or a series of volcanoes all the members will stand in certain common relations to the common hearth (the molten interior), yet each individual presents peculiar physical and chemical processes in respect to strength and frequency of action, to degree and form of fluidity, and to diversity of products — peculiarities not to be explained by differences of form or of elevation above the present surface of the sea. The colossal Sangay is as uninterrupted in eruption as the low Stromboli. Of two volcanoes near to each other, one sends forth pumice without obsidian, and the other emits both together;

one erupts only loose scoriæ; the other, lava flowing in narrow streams. Moreover in many cases these characteristic processes do not appear to have been always the same at different epochs. Rarity or absence of lava-streams does not characterise either continent so as to distinguish it from the other. Particular lava-streams may escape recognition from a variety of circumstances. Amongst these may be noticed an overlaying covering of tufa, ashes (rapilli), or pumice; the confluence, either at the same or different epochs, of several currents forming an extended lava-field, or space covered with fragments: and in an extensive plain, little cones of eruption, from which as at Lancerote streams of lava may have flowed, may have been destroyed. In the earliest conditions of our unequally cooling planet, in the first foldings of its surface, it appears to me very probable that there may have been an abundant flowing out of semifluid trachytic and doleritic masses, of pumice, and of perlite containing obsidian, from a complicated network of fissures above which no volcanic framework had yet arisen. The problem of such outpourings from simple fissures deserves the attention of geologists.

In the Mexican series of volcanoes the greatest and, since my American journey, the most celebrated phænomenon of upheaval is the elevation of the newly appeared Jorullo, and the emission of lava from it. This volcano, whose topography, established by measurements, I was the first to make known ([427]), presents by its position, intermediate between the two volcanoes of Toluca and Colima, and by its having broken forth over the great fissure of volcanic activity ([428]) which extends

from the Atlantic to the Pacific, an important and, for that reason, a much contested geological phænomenon. By tracing upwards the great stream of lava which had flowed from the new volcano, I succeeded in penetrating deep into the interior of the crater, and in setting up my instruments there. The theatre in which this great natural event took place was a wide and previously long-tranquil plain in the former province of Michuacan, more than 120 geographical miles from any other volcano; the time was the night of the 28th to the 29th of September 1759; and for two full months previously, uninterrupted subterranean noises had been heard. Unlike the wonderful "bramidos" of Guanaxuato in 1784, which I have described elsewhere ([429]), these noises were accompanied, as is more usually the case, by earthquake shocks, which phænomenon was altogether absent in the neighbourhood of Guanaxuato in 1784. The upheaval of the new volcano, at 3 A.M. in the morning of the 29th September, was announced on the preceding day by a phænomenon which in other eruptions usually marks, not their beginning, but their end. On the spot where the volcano now stands there was formerly a thick growth of Guava trees (*Psidium pyriferum*), of the fruit of which the natives are particularly fond. Labourers from the sugar-plantations of the Hacienda de San Pedro Jorullo, belonging to the wealthy proprietor Don Andres Pimentel, who was then living in Mexico, had gone out to gather guavas. When they returned to the hacienda, it was remarked, with astonishment, that their wide straw hats were covered with volcanic ashes. From this it would appear that, in what is now called the Malpais, probably at the foot of

the high basaltic cupola el Cuiche, fissures had opened, and that these ashes had been emitted from them before any change had been seen to take place in the plain. From a letter found in the Episcopal archives of Valladolid, written by Father Joaquin de Ansogorri, three weeks after the day of the first outburst, it would clearly seem that Father Isidro Molina (sent from the Jesuits' College of the neighbouring station of Patzcuaro "to administer spiritual consolation to the inhabitants of the Playas de Jorullo, greatly disquieted by the subterranean noises and the shocks of earthquake") was the first to recognise the increasing danger, and thus became the means of rescuing the whole of the scanty population.

In the first hours of the night the black ashes were already a foot high from the ground; every one fled to the heights of Aguasarco, an Indian village 2400 feet above the old plain of Jorullo. From these heights they saw (so says the traditional account) dreadful outbursts of flame over a wide extent of country; and "in the midst of the flames" (according to the expression of the actual spectators of the upheaval of the mountain) "there appeared a large shapeless lump (bulto grande) like a black castle (castillo negro)." In the then very sparsely inhabited state of the country (indigo and cotton were then very little cultivated) not a single human being lost his life in the violent and long-continued earthquake—which, however, as I found by manuscript notices ([430]), overthrew houses at the copper mines of Inguaran, in the little town of Patzcuaro, at Santiago de Ario, and for many miles further, not, however, beyond S. Pedro Churumuco.

At the Hacienda de Jorullo, in the confusion of the general flight by night, a deaf and dumb negro slave was forgotten and left behind. A Mestizo had the humanity to return and rescue him while the house was still standing; and the narrators still recounted with pleasure that he was found kneeling, with a consecrated taper in his hand, before the picture of Nuestra Señora de Guadalupe.

According to the widely prevailing and accordant native tradition, the eruption of large rocks, scoriæ, sand, and ashes was in the first days always accompanied by that of muddy water. In the account above alluded to, written on the 19th of October 1759, by a man who, with an accurate knowledge of the locality, was describing that which had just taken place, it is said expressly "que espele el dicho Volcan arena ceniza y agua." All eyewitnesses relate (I translate from the description in the official report "on the State of the Volcano of Jorullo," March 10, 1789, by the intendant Colonel Riaño and the German commissary Franz Fischer, who had entered into the Spanish service) that "before the dreadful mountain appeared (antes de reventar y aparecerse este terrible cerro) the earthquake-shocks and subterranean noises increased more and more; that on the day itself the flat ground was seen to rise visibly (se observó que el plan de la tierra se levantaba perpendicularmente), and the whole more or less swelled up so that blisters (vexigones) appeared, of which the largest is now the volcano (de los que el mayor es hoy el cerro del volcan). These raised blisters, of very different magnitude, and some of them of tolerably regular conical form, afterwards burst

(estas ampollas, gruesas vegigas ó conos diferentemente regulares en sus figuras y tamaños reventaron despues), and emitted boiling-hot mud (tierras hervidas y calientes), as well as scoriaceous rocks (piedras cocidas? y fundidas), which are still to be found, covered with black masses of stone, to an enormous distance."

These historic accounts, which could, indeed, be wished to have been more full, agree perfectly with all that I was able to learn fourteen years after Antonio de Riaño's ascent. To all my questions whether the "mountain castle" had risen gradually higher in the course of months or years, or whether it had been seen from the earliest days as a high summit, I could obtain no answer. Riaño's statement, that eruptions had continued to occur for the first sixteen or seventeen years, or up to 1776, was contradicted as untrue. The appearances of small eruptions of mud and water, in the first days, simultaneously with the burning scoriæ, were ascribed by the tradition to the drying up of two brooks which, rising on the western declivity of the mountain of Santa Ines (east therefore of the Cerro de Cuiche), watered plentifully the sugar-plantations of the former Hacienda de San Pedro de Jorullo, and flowed on far to the westward, to the Hacienda de la Presentacion. There is still shown, near their supposed source, the point where their once cold waters are said to have disappeared in a cleft when the eastern border of the Malpais was elevated. Running beneath the Hornitos, they become warmed, and reappear, according to the universal belief of the country-people, in two thermal springs. As the raised part of the Malpais is there broken off precipitously, they form two little waterfalls,

which I have drawn. Each has retained its former name, Rio de San Pedro and Rio de Cuitimba. I found the temperature of the steaming waters at this point 126°·9. The waters, during their long course, have become warmed only, but not acidulated. The test-papers, which I always carried about with me, were not at all altered by them; but farther on, near the Hacienda de la Presentacion, towards the Sierra de las Canoas, there gushes forth a spring impregnated with sulphuretted hydrogen, forming a basin twenty feet broad.

In order to obtain a clear idea of the complicated form in relief of the space of ground in which such remarkable upheavals took place, we must distinguish, hypsometrically and morphologically, (1) the situation of the volcanic system of Jorullo in relation to the mean level of the high plain of Mexico, (2) the convexity of the Malpais, which is covered by thousands of hornitos, (3) the fissure, upon which six volcanic mountain-masses have risen.

On the western declivity of the Cordillera Central de Mexico, which runs from S.S.E. to N.N.W., the plain of the Playas de Jorullo (only about 2560 feet above the level of the Pacific) forms one of the horizontal mountain-stages, or terraces, which everywhere in the Cordilleras interrupt the descent, and therefore retard more or less the change of temperature experienced. When from the central plateau of Mexico, 7000 French feet (7460 English) in mean height, we descend to the wheat-fields of Valladolid de Michuacan, to the pretty Lake of Patzcuaro with its small inhabited island Janicho, and into the meadows around Santiago

de Ario, which Bonpland and I found decked with the since then so well-known flowers of the dahlia, we have not yet lessened the altitude a thousand feet. But when we pass from Ario, on the steep declivity above Aguasarco, to the level of the old plain of Jorullo, in that very short distance we diminish the absolute height about 4000 feet.(431) The round convex part of the upheaved plain is about 12,800 feet across. The volcano of Jorullo itself, and the five other mountains which rose together with it upon the same fissure, are so placed that only a small part of the Malpais falls to the east of them. The number of hornitos is therefore much greater on the western side; and when in the early morning I came out of the Indian hut in which I had passed the night, in the Playas de Jorullo, or when I ascended a part of the Cerro del Mirador, I saw the black volcano rise very picturesquely above the countless columns of white smoke issuing from the hornitos (the little ovens or furnaces). Both the houses of the playas and the basaltic hill Mirador are on the level of the ancient unvolcanic or, to speak more cautiously, not upheaved ground. The beautiful vegetation, in which a host of salvias bloom under the shadow of a new kind of fan palm (Corypha pumos) and a new kind of alder (Alnus jorullensis), contrasts with the desert nakedness of the Malpais. The comparison of the height of the barometer (432) at the point where the upheaving in the playas begins, to a point situated immediately at the foot of the volcano, gives a difference of 473 feet. The house which we inhabited stood about 3200 feet from the edge of the Malpais. This edge is a small vertical precipice only twelve feet

high, over which the waters of the brook, which had become heated (the Rio de San Pedro), fall. The best examination which I was thus enabled to make of the face of the precipice showed black horizontal beds of mud or clay, intermixed with sand or rapilli. At other points, which I had not seen, Burkart observed "at the perpendicular edge of the upheaved ground, where it is difficult of ascent, a light-grey, much-weathered, not dense basalt with many grains of olivine." ([433]) This accurate and experienced observer ([434]), when on the spot, imbibed, as I had done, the impression of a blistering of the surface by elastic vapours, contrary to the opinion of celebrated geologists ([435]), who ascribed the convexity, found by me by direct measurement, solely to the greater mass of the outpoured lava more immediately around the foot of the volcano.

The many thousand small cones of eruption (or more strictly of a roundish or oblong shape, like a baker's oven), which are pretty equably distributed over the upheaved surface, are generally about from four to ten feet high. Much the greater number are on the west side of the great volcano; the eastern portion, towards the Cerro de Cuiche, being scarcely one twenty-fifth of the whole upheaved area of the playas. The hornitos are composed of weathered balls of basalt, consisting of concentric shells, of which I often counted as many as twenty-four or twenty-eight. The balls are rather spheroids than spheres, generally from sixteen to nineteen inches in diameter; but there are also many others varying between one foot and three feet. The black basalt is pervaded by hot vapours, and has become earthy; but the nucleus is more dense, while the shells, when sepa-

rated, show yellow stains of oxide of iron. Singularly enough, the soft bed of clay which unites the balls together has also a curved lamellar structure insinuating itself into all the interstices between the balls. At first sight I asked myself whether the whole, instead of consisting of weathered basaltic balls containing a little olivine, might not be masses in which a formative process had been disturbed while taking place. This view is opposed by the analogy of the actual hills of basaltic balls interspersed with beds of clay and marl which are found, often of very small dimensions, in the Mittelgebirge of Bohemia, sometimes isolated, and sometimes crowning both extremities of long basaltic ridges. Some of the hornitos are either so loosely cemented, or have such considerable internal cavities, that, when mules are urged to pass over the flatter ones amongst them, the animals' fore feet sink in, whereas, in similar trials, the hills constructed by termites (ants) do not give way.

I did not find any scoriæ, or fragments of older rocks which had been broken through, enveloped in the basalt of the hornitos, as was the case in the lavas of the great Jorullo. The circumstance which particularly justifies the name of hornos, or hornitos (ovens), is that the smoke issues from them, not at the top, but at the sides. (I speak of the time when I saw them and wrote in my journal, Sept, 18, 1803.) In 1780 it was still possible to light cigars at them by fastening the cigar to a stick pushed in two or three inches deep; in some places the air was so much heated by their neighbourhood, as to oblige the passer-by to turn out of his way. Notwithstanding the cooling-down which, according to the unanimous testi-

mony of the Indians in the neighbourhood, had taken place in the last twenty years, I found the temperature in the cracks of the hornitos generally between 199°·4 and 203°; and standing at a distance of fully twenty feet from some of the hills, where not touched by any vapours, the temperature of the air was still 108°·5 and 116°·2, when the proper temperature of the playas at the same hour was barely 77°. The weak sulphuric vapours discoloured test-paper, and for some hours after sunrise were seen to rise to a height of from 60 to 64 feet. The view of the columns of smoke was most striking in the cool of the early morning. Towards noon, and even at 11 A.M., they had sunk so low as only to be visible when quite near. In the interior of several of the hornitos, we heard a sound like the fall or rush of water. As already remarked, they possessed little solidity, and when Burkart visited the Malpais, twenty-four years after me, he found none sending forth smoke, the temperature of most of them was no higher than that of the surrounding air, and in many all regularity of shape had been obliterated by the effects of rain, &c. Burkart found near the principal volcano small cones of a brownish-red conglomerate composed of very loosely connected rounded or angular pieces of lava. There is still seen, in the midst of the area covered by the hornitos, the remains of a former rising ground, running east and west, and drawn on my map, on which the farm-buildings of San Pedro had rested; its preservation at the foot of the great volcano excites astonishment. Part of it only is covered with volcanic sand (or burnt rapilli). The projecting basaltic rock, overgrown with aged trunks of Ficus indica and Psidium, is assuredly, as

well as the Cerro del Mirador and the high mountain masses whose curve bounds the plain to the eastward, to be regarded as having existed before the catastrophe.

I have still to describe the great fissure over which six volcanoes (not touching each other) have been raised, in a direction running generally from S.S.W. to N.N.E., but in the three southernmost almost S. to N. The fissure (1700 toises in length) is therefore a little curved; its general direction is almost perpendicular to that which I have assigned to the volcanoes of Mexico, taken from sea to sea. Such differences need not excite surprise, inasmuch as the partial relations of a single group, and those of the great masses across an entire continent, ought not to be confounded. Thus, the long ridge of Pichincha has not the same direction as the system of the Quito volcanoes; and in non-volcanic chains, *e. g.* in the Himalaya, the highest points are often far from being situated in the general elevation-line of the chain, being instead, on shorter snowy ridges, almost at right angles to it.

Of the six volcanic hills raised over the fissure above spoken of, the three southernmost, between which the route to the copper mines of Inguaran passes, are in their present state the least interesting. They are no longer open, and are entirely covered with greyish-white volcanic sand, not consisting, however, of pumice, of which, or of obsidian, I saw no signs in this district. At Jorullo, as at Vesuvius according to the statements of Von Buch and Monticelli, the last and covering fall of ashes seems to have been the white one. The fourth mountain (going northward) is the great and proper volcano of

Jorullo, whose summit, notwithstanding its small elevation (4265 feet above the sea, 1150 feet above the Malpais at its foot, and 1680 feet above the old surface of the playas), was not attained without difficulty by Bonpland, Carlos Montufar, and myself, Sept. 19th, 1803. We thought we should be most sure of reaching the crater, then still filled with hot sulphurous vapours, by climbing the steep side of the great lava-stream which had burst forth from the summit itself. Our way lay over a curled scoriaceous cauliflowerlike lava, which gave a clear ringing sound when struck. Parts of it have a metallic lustre ; others are like basalt, and are full of fine grains of olivine. When we had thus gained the top of the lava by an ascent of 721 feet in vertical height, we turned to the very steeply inclined white cone of cinders (on which, from its great steepness, the traveller is liable to painful hurts from the sharp jagged lava). The upper margin of the crater, on the south-western part of which we placed our instruments, forms a ring only a few feet in breadth. We afterwards took the barometer down into the oval crater of the truncated cone, where we found the temperature of the air issuing from a cleft 200°·7. We were now 150 feet below the margin ; and the depth of the deepest part of the hollow, which the thick sulphurous vapours forbade our reaching, appeared to us to be about as much again. The discovery which interested us most was that of several sharply defined white fragments of a rock containing felspar, three or four inches in size, baked into the black basaltic lava. I took them at first for syenite (436); but by Gustav Rose's accurate examination of a specimen which I brought home, they belong rather to the granite forma-

tion, which Burkart also saw crop out under the syenite of the Rio de las Balsas. Rose said, "the enclosure is a mixture of quartz and felspar. The dark-green spots appear to be not hornblende, but mica fused with some felspar. The white baked-in fragment has been split by volcanic heat; and in the crack, white tooth-shaped molten threads run from one edge to the other."

More to the north than the great volcano of Jorullo, and than the scoriaceous lava-summit which it threw out in the direction of the old basalt of the Cerro del Mortero, follow the two last of the six volcanoes. They appear to have been at first very active; for the natives still call the extreme one the "volcancito." A wide fissure which has opened to the westward bears in this part traces of a destroyed crater. The great volcano appears, like Epomeo in Ischia, to have poured forth a great stream of lava only once. There is, historically, no reason to suppose that it continued to do so beyond the immediate epoch of the great outburst; for the letter of Father Joaquin de Ansogoni, written twenty days after the first eruption, speaks only of the best means to be adopted for the pastoral care of the dispersed country-people, who had fled from the catastrophe, and for the next thirty years we are entirely without documentary evidence. As tradition speaks very generally of "fires covering so great a space," we may suppose that all the six hills over the great fissure, and all the part of the Malpais on which the hornitos appeared, were burning at the same time. We may in some degree infer the heat which must have prevailed in the surrounding atmosphere from the temperatures still measured by me after the lapse of forty-

three years: we are reminded thereby of the early state of our planet, when under every latitude, and for long periods of time, the temperature of the atmosphere and the distribution of organic life were subject to modifications arising from the thermic influence of the interior acting through deep fissures.

Since my description of the hornitos surrounding Jorullo, many analogous features in different parts of the world have been compared to them; they, however, still appear to me to stand very much alone in respect to their internal composition. If we are to give the name of cones of eruption to all elevations emitting vapours, the hornitos certainly deserve to be called "fumaroles;" but the term "cones of eruption," applied to them, would lead to the erroneous supposition of their showing traces of having erupted scoriæ, or even poured forth lava, as many cones of eruption have done. Wholly different, for example (to recall a phænomenon of greater magnitude), in Asia Minor, on the former limits between Mysia and Phrygia, in the ancient "burnt land" (Katakekaumene), "where it is dangerous to live on account of earthquakes," are the three orifices which Strabo calls "φῦσαι" (bellows), and which have been rediscovered by the meritorious traveller William Hamilton.(437) Cones of eruption, such as are seen in the island of Lancerote, at Tinguaton, or in Lower Italy, or (only 20 feet high) on the declivity of the Kamtschatkan volcano Awatscha (438), which was ascended by my friend and Siberian travelling companion, Ernest Hoffmann, in July 1824, consist of scoriæ and ashes surrounding a little crater which has emitted them, and which has in turn had its margin raised

by them. In the hornitos there is nothing resembling a crater; and they consist (which is an important character) of mere basaltic balls of concentric separable shells, without any intermission of loose angular scoriæ. At the foot of Vesuvius, at the great eruption of 1794 (as also at earlier epochs), there were formed, arranged over a longitudinal fissure, eight different little craters of eruption, "bocche nuove," the so-called "parasitic" eruption-cones, pouring forth lava, which would of itself distinguish them altogether from the Jorullo hornitos. "Your hornitos," wrote Leopold von Buch to me, "are not cones heaped up by the fall of erupted substances; they have been upheaved *directly* from the interior of the earth." The same great geologist compares the origin of the volcano of Jorullo itself to that of the Monte Nuovo in the Phlegræan Fields. The same view, in respect to the elevation of the six volcanic mounts, impressed itself, as the most probable one (see above, pp. 292, 293), on Colonel Riaño and Commissary Fischer in 1789, on myself, at first sight, in 1803, and on Oberbergrath Burkart in 1827. In regard to *both* the "new mountains" (Monte Nuovo and Jorullo), which arose in 1538 and 1759, the same questions presented themselves. Respecting the Italian Mount, fuller accounts have been collected nearer to the time of the catastrophe, and derived from more qualified observers, by Falconi, Pietro Giacomo di Toledo, Francesco del Nero, and Porzio. One of these (the most learned), the celebrated Porzio, says, "Magnus terræ tractus, qui inter radices montis, quem Barbarum incolæ appellant, et mare juxta Avernum jacet, sese *erigere videbatur* et montis subito nascentis figuram

imitari. Iste terræ cumulus aperto veluti ore magnos ignes evomuit, pumicesque et lapides cineresque."(439)

From the geological description of the volcano of Jorullo which I have here completed, we pass to the more eastern part of Central Mexico. Unmistakable lava-currents, of which the mass is chiefly basaltic, have been poured forth by the Peak of Orizaba, according to the most recent and interesting researches of Pieschel (March 1854)(440) and H. de Saussure. The rock of the Peak of Orizaba, like that of the great volcano of Toluca(441), which I ascended, is composed of hornblende, oligoclase, and some obsidian, whereas the fundamental mass of Popocatepetl is a Chimborazo rock composed of very small crystals of oligoclase and augite. At the foot of the eastern declivity of Popocatepetl, west of the town la Puebla de los Angeles, I found, on the Llano de Tetimpa (where I measured a base for determining the heights of the two great nevados which bound the valley of Mexico, Popocatepetl and Iztaccihuatl), an extensive and in some respects perplexing lava-field (or field of rough fragments of lava). It is called the Malpais of Atlachayacatl (the latter being the name of a low trachytic dome, on the side of which the Rio Atlaco takes its rise); it extends from east to west, or almost at right angles to the volcanoes, rising abruptly from about 64 to 85 feet above the adjacent plain. From the Indian village of San Nicholas de los Ranchos to San Buenaventura, I estimated the length of the Malpais at above 19,200 feet, and its breadth at about 6400 feet. On it blocks of black lava, only scantily overgrown here and there with lichen, of fantastic wildness of form and position, contrast with

the yellowish-white covering of pumice which invests all around. The pumice consists here of fragments of coarse texture, of two or three inches diameter, in which there are sometimes crystals of hornblende. This coarser pumice-sand is different from the very fine-grained one which on Popocatepetl itself, near the rock of el Frayle and at the limit of perpetual snow, makes the ascent so dangerous, because, when set in motion on the steep declivity, the rolling mass of sand threatens to overwhelm everything. Whether this malpais (the Spanish term for these fields of lava-ruins, called in Sicily sciarra viva, and in Iceland Odaada Hraun) belongs to old successively superimposed lateral eruptions from Popocatepetl or to the rounded conical mountain Tetljolo (Cerro del Corazon de Piedra), I cannot decide. It is a geologically important circumstance, that further to the east, on the route to the little fortress of Perote (the old Aztec Pinahuizapan), between Ojo de Agua, Venta de Soto, and el Portachuelo, the volcanic formation of coarse-textured white friable pearlstone (442) rises by the side of a probably tertiary limestone (marmol de la Puebla). This pearlstone is very similar to that of the conical hill of Zinapecuaro (between Mexico and Valladolid), and contains, besides laminæ of mica and lumps of imbedded obsidian, glassy bluish-grey, sometimes reddish, stripes resembling jasper. The extensive "pearlstone district" is here covered with fine-grained sand consisting of weathered pearlstone, which at first sight might be mistaken for granitic sand, and which, notwithstanding their affinity in respect of origin, may easily be distinguished from the greyish-white pumice

sand. The latter belongs more to the immediate vicinity around Perote,—to the plateau, more than 7000 feet high, which lies between the two volcanic chains, running north and south, of Popocatepetl and Orizaba.

When, in proceeding from Mexico to Vera Cruz, one begins to descend from the heights of the non-quartzose trachytic porphyry of Vigas towards Canoas and Jalapa, one twice passes over fields of fragments of scoriaceous lava,—the first time between the station of Parage de Carros and Canoas or Tochtlacuaya, the second time between Canoas and the station of Casas de la Hoya. The first is called Loma de Tablas, on account of the many upright basaltic slabs of oliviniferous lava, and the second simply the Malpais. A small ridge of the same trachytic porphyry full of glassy felspar, which (near la Cruz Blanca and Rio Frio) forms the eastern boundary of the Arenal (pearlstone sand-fields), divides the Loma de Tablas from the much more extensive Malpais. Those among the country-people who are well acquainted with the district, affirm that the lines of scoriæ are prolonged towards the S.S.W., therefore towards the Cofre de Perote. Having myself ascended the Cofre and made many measurements on it(443), I have been little disposed to infer, from what is indeed a very probable prolongation of this stream of lava (marked as such in my "Profiles," tab. 9 and 11, as well in the "Nivellement barométrique"), that it had actually flowed from that singularly shaped mountain. The Cofre de Perote, which is indeed nearly 1400 feet higher than the Peak of Teneriffe, but which yet is an inconsiderable mountain compared to its colossal neighbours Popocatepetl and Orizaba, forms, like Pichincha,

a long rocky ridge, on the southern extremity of which stands the cubical rock (la Peña) whose shape has given occasion to the ancient Aztec name Nauhcampatepetl. I found, on my ascent of the mountain, no trace of a fallen in crater, or of lateral eruption-openings; nor did I find any masses of scoriæ, or any obsidian, pearlstone, or pumice belonging to it. The blackish-grey rock is very uniform, composed of much hornblende and a kind of felspar which is not glassy felspar (sanidine), but oligoclase, which would stamp the whole of the rock which is not porous, as a dioritic trachyte. I describe the impressions which I imbibed. If the substances which cover this black desolate Malpais, on which I have dwelt purposely as opposing too partial views of volcanic manifestations of force from the interior, have not flowed from a lateral opening in the Cofre de Perote itself, yet the upheaval of that isolated mountain, 13,550 feet high, may have occasioned the origination of the Loma de Tablas. At such an upheaval, longitudinal fissures and a ramifying fissured network may have been opened for a considerable distance around by the "folding" of the surface; and from these fissures molten substances may have flowed directly, either as dense masses or as scoriaceous lavas, without the intervention or formation of the framework of open cones, or of elevation-craters. We know that we may look in vain, in the great mountains of basalt and porphyritic schist, for either central points (crater mountains) or lower ridge-encircled hollows, to which their common origin might be ascribed. Science gains by the most careful distinction between whatever is genetically different in phænomena,—

between the formation of conical mountains with open craters on their summits, and lateral openings,—or of elevation-craters and maars,—and the upheaval of closed domes or open cones, and the direct emission of substances from fissures. The greater variety of views necessarily called forth by a more extended horizon of observation, and the strict critical comparison of that which we find in nature with what was previously supposed to be the only mode of origin, is itself a most powerful stimulus to investigation. Even on European ground, in the island of Eubœa rich in hot springs, within historic times, in the great plain of Lelantum —at a distance from any mountains,— a great stream of lava was poured forth from a fissure. ([444])

In the next group of volcanoes, the Central American one, in which eighteen may still be regarded as active, four (Nindiri, el Nuevo, Conseguina and San Miguel de Bosotlan) have been recognised as yielding streams of lava. ([445]) The mountains of the third group, that of Popayan and Quito, have, for more than a century been reputed to send forth no lava-streams, but solely masses of unconnected glowing scoriæ, ejected from the one summit-crater and often seen to glide in succession down the mountain side. La Condamine was already of that opinion ([446]) when he left the highland of Quito and Cuenca, in the spring of 1743. Fourteen years later, after returning from an ascent of Vesuvius (4th June, 1755), on which he had accompanied the sister of Frederick the Great, the Margravine of Bavaria, he took occasion, at a meeting of the Academy, to express himself strongly as to the entire absence of proper streams of lava (laves coulées par torrens de matières liquéfiées)

in the volcanoes of Quito. His "Journal d'un Voyage en Italie," read at the meeting of the 20th of April 1757, was first published in 1762, in the Memoirs of the Paris Academy, and is of some importance in the history of the recognition of extinct volcanoes in France, because in it La Condamine, without being aware of the certainly earlier statements of Guettard ([447]), expressed himself with great distinctness and sagacity as to the existence of ancient crater-lakes and extinct volcanoes in Middle and Northern Italy, and in the south of France.

The striking contrast between the thus early recognised existence of narrow undoubted streams of lava in Auvergne, and the often too positively and unreservedly asserted absence of any flow of lava in the Cordilleras, engaged my earnest attention during the whole of my expedition. My journals written at the time are constantly filled with considerations on this problem, of which I long sought the solution in the absolute altitude of the summit, and in the height of the escarpment surrounding the deep depression on cones rising from mountain plateaus 8000 or 9000 feet above the sea But we now know that Macas (Sangay), a scoriæ-emitting Quito volcano 17,000 feet high, is more uninterruptedly active than the lowly Izalco and Stromboli; and we also know that Antisana and Sangay on the east have free and open declivities towards the plains of the Napo and the Pastaza, as have Pichincha, Iliniza and Chimborazo on the west, towards the water-sheds of the Pacific. In many instances the upper portion rises without any surrounding escarpment, more than 8000 or 9000 feet above the high plateau. Moreover, all these

heights above the level of the sea (regarded, perhaps not quite correctly, as the mean level of the earth's surface) are inconsiderable in relation to what we may suppose to be the depth of the seat of volcanic activity, and of the temperature required for the fusion of rocks.

The only phenomena resembling narrow flows of lava which I ever discovered in the Cordilleras of Quito, are those presented by the colossal Antisana, whose height I determined by trigonometric measurement at 19,132 feet. As in this case configuration affords us the best criterion, I will avoid the systematic expression "lava," as apt to convey too limited a sense in regard to origin, and will use, in a purely objective sense terms equivalent to the French expression "traînées de masses volcaniques." The great mass of Antisana forms, at a height of 13,455 feet, an almost oval plain, of which the longest diameter is about 80,000 feet, and from which the snow-covered portion of the volcano rises like an island. The highest summit is rounded off into a dome, which is connected by a short jagged ridge with a truncated cone lying to the north of it. On this high plain, which is partly desert and sandy, and partly covered with grass, and on which dwell a very courageous race of bulls (which, owing to the small amount of atmospheric pressure, often bleed at the mouth or nostrils when stimulated to any great muscular exertion), there is a small hacienda, a single house, in which we passed four days with a temperature varying between 38°·7 and 48°·2. The plain, which is not surrounded by any escarpment, as in craters of elevation, bears all the signs of being an ancient lake-bottom. The Laguna Mica, west of the Altos de la Moya, may be regarded as the

remains of a former watery covering. At the limit of perpetual snow, the Rio Tinajillas takes its rise, which afterwards, under the name of the Rio de Quixos, becomes an affluent of the Maspa, the Napo and the Amazons. Two narrow wall-like elevations, which in my topographical sketch of Antisana I have marked as "coulées de lave," and which the natives call Volcan de la Hacienda and Yana Volcan (Yana, in the Quech-hua language, signifies black or brown), run like bands from the foot of the volcano to the snow-line on the south-western and northern declivities, and extend, as it appears to me, with very moderate angles of inclination in a N.E. and S.W. direction about 13,000 feet over the plain. With a very small breadth, they are about 192 to 213 feet above the ground of the Llanos de la Hacienda de Santa Lucia, and del Cuvillan. Their declivities are everywhere very abrupt and steep, even at the extremities. They consist, in their present state, of scaly and, for the most part, sharply angular fragments of a black basaltic rock, without olivine and hornblende, but containing a few small crystals of white felspar. The mass has often a pitchlike lustre, and contains interspersed obsidian, which may be still more distinctly recognised, and in great abundance, at Cueva de Antisana, of which we found the height 15,942 feet. It is not, properly speaking, a cave, but only a sort of shelter formed by masses of rock which have fallen against each other, which is resorted to by the herdsmen who ascend the mountain, and in which we took refuge during a violent hail-storm. It is a little to the north of the Volcan de la Hacienda. In the two narrow rocky ridges, which have the appearance of cooled lava-streams, the

slabs and blocks are partly scoriaceous, and even puffed up like foam at their edges, and partly weathered and mixed with earthy detritus.

Analogous, but more complex, phænomena are presented by another, also band-like, assemblage of rocks. On the eastern declivity of Antisana, nearly 1300 feet lower in vertical height than the plain of the Hacienda, in the direction of Pinantura and Pintac, there are two small circular lakes, of which the northernmost is called Ansango, and the southernmost, Lecheyacu. The first has in it an island rock, and (which is very decisive) is surrounded by rolled pumice. Each of these lakes marks the commencement of a valley; the two valleys unite, and their broader prolongation bears the name of the Volcan de Ansango; from the margins of the two lakes there proceed narrow lines of rocky fragments quite similar to those above described, which do not *fill up* the valleys, but rise in their middle, as dikes of 200 and 250 French feet (213 and 266 English). A glance at the topographical plan in the "Atlas géographique et physique" of my American journey (pl. 26) will render these relations clearer. The blocks, here also, are partly sharp-cornered, and partly scoriaceous at the edges, and even have a burnt appearance. The mass is black, and resembles basalt with scantily interspersed glassy felspar; some fragments are a blackish brown, and have a faint pitchy lustre. There is, however, an entire absence of the olivine which is so abundant on the Rio Pisque, and at Guallabamba, where I saw basaltic columns 72 feet high, and fully 3 feet in diameter, containing both olivine and hornblende interspersed. In the Ansango dike many slabs, split into that form by weathering,

indicate porphyritic schist. All the blocks have a yellowish grey crust from weathering. As the line of rocky fragments (the Spanish-speaking natives call it los derrumbamientos, la reventazon) extends from the Rio del Molino, not far from the hacienda of Pintac, up to the small pumice-surrounded crater lakes, the impression which naturally presented itself was, that the hollows now filled with water are the orifices through which those fragments came to the surface. A few years before my arrival in the country, without any preceding sensible agitation of the ground, the rocky fragments were in a state of motion down the declivity for weeks, and some houses at Pintac were overthrown by their impetus and pressure. They are still without any trace of vegetation; which is beginning to appear, though sparingly, on the doubtless older and more weathered blocks on the high plain of Antisana.

What name ought we to give to the particular manifestation of volcanic activity, whose effects I have been describing? (448) Have we here to do with lava-streams? or only with semiscorified and glowing masses, ejected disconnectedly but in close succession, as has been seen to take place in very recent times on Cotopaxi? May it even be possible that the dykes of stones of Yana Volcan and Ansango may have been fragmentary masses, which, being loosely heaped up, and therefore imperfectly supported, in the interior of the volcano, may have been displaced by earthquakes, and then by their fall and shock have occasioned small local agitations, and thus have been ejected without any renewal of higher temperature in the volcano? Or are none of the three very different manifestations of volcanic ac-

tivity, which have been alluded to, applicable in this case? and have the linear collections of rocky fragments been actually elevated over fissures at the places where we now see them (at the foot or in the vicinity of a volcano)? The two walls of fragments (on the high and little inclined plain) called Volcan de la Hacienda and Yana Volcan, and which I formerly spoke of (conjecturally only) as cooled lava-streams, still appear to me, speaking from recollection at so great a distance of time, to lend but little support to the view referred to in the last sentence. In the Volcan de Ansango, in which the lines of fragments can be traced uninterruptedly, like a river-bed, to the pumice-covered margins of two small lakes, there is nothing in the angle of fall, *i.e.* the difference of level between Pinantura (9477 feet) and Lecheyacu (12,150 feet), for a distance of about 7700 toises (16,413 yards), inconsistent with the present state of our knowledge as to the small average angle of inclination in lava-currents. The difference of level, 2673 feet, gives an inclination of 3° 6′. A partial rise of the ground in the middle of the lowest part need not be regarded as an obstacle, as cases of fluid masses overriding such rises have been observed; for example in the eruption of Skapta Jokul in Iceland, in 1783 (Naumann, Geognosie, Bd. i. s. 160).

The word lava does not designate any particular mineralogical composition of rock; and whereas Leopold von Buch says that all is lava which flows in the interior of a volcano, and is capable by its fluidity of forming fresh beds of deposit, I would add that fluidity is not essential to such changes. Already, in the first description (449) of my attempt to reach the summit of

Chimborazo (first published in 1837 in Schumacher's Astronomisches Jahrbuch), I had expressed this conjecture, when speaking of the remarkable pieces of augitic porphyry which, on the 23rd June 1802, I collected in loose fragments of twelve or fifteen inches diameter at a height of 19,000 feet, on the narrow rocky ridge leading to the summit. They were porous, and of a reddish colour, minutely cellular, and the cells shining. Some had a blackish tinge, and in some cases were of very light weight, like pumice, and looked as if freshly altered by fire. They have not, however, flowed lava-like in currents, but have probably been expelled from fissures on the declivity of the previously upheaved mountain dome. This explanation of their origin would find great support in the view entertained by Boussingault, who considered the volcanic cone itself to be "a heap of angular fragments of trachyte, upheaved in a solid state, and piled upon each other without any definite arrangement. As a heap of broken fragments of rock occupy more space than would the same quantity of material before being fractured, there remain large intervening hollow spaces in which, by mutual pressure and shock (apart from the effect of the force of volcanic vapours), movement arises." I am far from doubting the occurrence of such fragments and of such hollows, which in the Nevados became filled with water, although the fine, regular, and generally quite vertical, columns of trachyte of the Pico de los Ladrillos and Tablahuma on the Pichincha, and, most of all, those above the little lake of Yana Cocha, on Chimborazo, appear to me to have been formed on the spot. My long and dearly

valued friend Boussingault, whose chemico-geological and meteorological views I always delight in sharing in, regards what is called the Volcano of Ansango, and which I now look upon rather as an eruption of fragments from two small lateral craters (on the west side of Antisana, not far from Chussulongo), as an elevation or upheaval of blocks ([450]) over long fissures. Having examined this region, with much sagacity, thirty years after me, he lays much stress on the analogy which the geological relations of the eruption of Ansango to Antisana appeared to him to present with those of Yana Urcu (of which I had made a special topographical plan) to Chimborazo. I was myself less inclined to believe in an elevation over fissures situated immediately below the whole linear extent of the Ansango series of fragments, because, as I have said, they can be traced up to two orifices now filled with water. Unfragmentary wall-like elevations of great length and uniform direction are not unknown to me, having seen and described such in Chinese Tartary, consisting of horizontal banks of granite. ([451])

Antisana had a fiery eruption ([452]) in 1590, and another in the beginning of the last century, probably in 1728. Near the summit, on the N.N.E. side, there is remarked a black mass of rock on which even fresh fallen snow does not remain. For several days in the spring of 1801, at a time when the summit was on all sides perfectly free from clouds, a column of black smoke was seen to ascend from this point. On the 18th of March 1802, Bonpland, Carlos Montufar, and I, arrived on a rocky ridge covered with pumice and black basaltic scoriæ, in the region of perpetual snow, at

a height of 18,141 feet, therefore 2358 feet higher than Mont Blanc. The snow near the rock was, at several places, solid enough to bear our weight, a circumstance which is very rare within the tropics. (The temperature of the air was from 28°·8 to 34°·5.) On the southern declivity, by which we did not ascend, at the Piedro de Azufre, where the rock scales off from the effects of weathering, masses of pure sulphur, ten or twelve feet long and two feet thick, are found: there are no sulphur springs in the neighbourhood.

Although in the eastern Cordillera, Antisana, and especially its western declivity (from Ansango and Pinantura towards the little village of Pedregal), is separated from Cotopaxi by the extinct volcano of Passuchoa ([453]) (with its crater, la Peila, recognisable at a great distance), by the Nevado Sinchulahua, and by the less lofty Rumiñaui; yet there is a certain similarity in the rocks of which these two great volcanoes are composed. Beginning from el Quinche, the whole eastern Cordillera has produced obsidian, and yet el Quinche, Antisana, and Passuchoa belong to the basin in which the city of Quito is situated, while Cotopaxi bounds another basin, that of Lactacunga, Hambato, and Riobamba. These two basins are divided from each other by the little mountain knot of the Altos of Chisinche, and the small dimensions of this dividing wall renders more striking the circumstance, that the waters of the northern side of Chisinche flow through the Rios de San Pedro, de Pita, and de Gualllabamba, into the Pacific, while the waters of the southern side flow through the Rio Alaques, and the Rio de San Felipe into the Amazons and the Atlantic Ocean. The

connection of the two Cordilleras by mountain knots and mountain walls or dikes (sometimes low like the Altos de Chisinche, just mentioned; and sometimes as high as Mont Blanc, as over the Passo del Assuay) appears to be a more recent, and also a less important, phenomenon, than the elevation of the parallel chains themselves. As Cotopaxi, the greatest of all the Quito volcanoes, presents, in its trachytic rock, many analogies with Antisana, so also we find on the slopes of Cotopaxi, lines of rocky fragments similar to those which have occupied us above, and more numerous.

We felt a great desire to trace up these lines of fragments to their origin, or rather to the place where they are hidden under the covering of perpetual snow. We ascended on the south-west slope of the mountain, from Mulalo (Mulahalo), by the side of the Rio Alaques, which is formed by the Rio de los Baños, and the Rio Barrancas, to Pansache (12,066 feet high), where we occupied the roomy Casa del Paramo, on the grassy plain el Pajonal. Although much snow had fallen sporadically at night, we succeeded, keeping to the east of the celebrated Cabeza del Inga, in arriving, first at the Quebrada and Reventazon de las Minas, and subsequently, keeping still more to the east, over the Alto de Suniguaicu, at the Ravine of the Lion's Mount (Puma Urcu), where the barometric readings gave an elevation of 14,470 feet. Another line of fragments, which, however, we only saw from a distance, ran from the eastern part of the snow-covered cone of cinders, towards the Rio Negro (a tributary of the Amazons), and towards Valle Vicioso. Whether these blocks, which we suppose to have been glowing masses of

scoriæ, molten only at their edges,—sometimes angular and sometimes roundish, of six or eight feet diameter, rarely scaly, like those on Antisana,—have all been thrown up to great heights from the summit-crater, and, falling down on the declivity, have had their movement accelerated by the rush of melted snow water; or whether, without having been thrown up into the air, they have been expelled from lateral fissures of the volcano, as the word reventazon would indicate, remains uncertain. Returning soon from Suniguaicu and the Quebrada del Mestizo we examined the long and broad ridge, which, stretching from N.W. to S.E., connects Cotopaxi with the Nevado de Quelendaña. Here the blocks arranged in line are wanting, and the whole appears a dyke-like elevation, on which the small conical Mount el Morro rises, and nearer to Quelendaña (which has the shape of a horse-shoe,) there are several marshes and two small lakes, the Lagunas de Yauricocha and de Verdecocha. The rock of el Morro and of the whole linear volcanic elevation was greenish-grey porphyritic schist, in beds or strata eight inches thick, dipping very regularly towards the east at an angle of 60°. Of proper currents of lava, there was nowhere any trace. ([454])

There is an analogy between what takes place in the Island of Lipari, rich in pumice, where on the north of Caneto a lava-stream of pumice and obsidian descends from the well-preserved extinct crater of the Monte di Campo Bianco towards the sea, in which it is remarkable that the fibres of the pumice are parallel to the direction of the stream ([455]), and the local relations, which were carefully examined by me, of the extensive pumice-

stone quarries situated four miles from Lactacunga. These quarries, in which the pumice-stone is in horizontal layers, having quite the appearance of a rock in situ, excited the astonishment of Bouguer in 1737. (456) He says: "On ne trouve sur les montagnes volcaniques que de simples fragments de pierre-ponce d'une certaine grosseur; mais à sept lieues au sud du Cotopaxi, dans un point qui répond à notre dixième triangle, la pierre-ponce forme des rochers entiers; ce sont des bancs parallèles de 5 à 6 pieds d'épaisseur dans un espace de plus d'une lieue carrée. On n'en connoit pas la profondeur. Qu'on s'imagine quel feu il a fallu pour mettre en fusion cette masse énorme, et dans l'endroit même où elle se trouve aujourd'hui; car on reconnoit aisément qu'elle n'a pas été derangée et qu'elle s'est refroidie dans l'endroit où elle a été liquifiée. On a dans les environs profité du voisinage de cette immense carrière; car la petite ville de Lactacunga, avec de très jolis édifices, est entièrement bâtie de pierre-ponce depuis le tremblement de terre qui la renversa en 1698."

The pumice-stone quarries are situated near the Indian village of San Felipe, in the hills of Guapulo and Zumbalica, which are 512 feet above the high plain, and 9990 feet above the sea. The uppermost layers of pumice-stone are thus 500 or 600 feet below the level of Mulalo, the villa of the Marques de Maenza, situated at the foot of Cotopaxi, and which was built entirely of blocks of pumice-stone: it was once a fine piece of architecture, but has been reduced to ruins by frequent shocks of earthquake. The subterranean quarries are at unequal distances from Tungurahua and Cotopaxi, being 32 geographical miles from the former,

and only 16 from the latter. They are reached by a gallery. The workmen assured me, that square blocks of 20 or 21 feet could be obtained entire and without cross cracks, from the horizontal solid beds, of which a few are surrounded by muddy pumice detritus. The pumice-stone, partly white and partly bluish grey, is of very fine texture, and has long fibres of a silky lustre. The parallel fibres have sometimes a knotted appearance, and they then show a curious structure. The knots are formed by roundish morsels of finely porous pumice, about a tenth of an inch thick, round which the long fibres curve so as to enclose them. Brownish black mica, in six-sided small tablets, white oligoclase crystals, and black hornblende, are scantily interspersed; but no glassy felspar, which elsewhere, as at Camaldoli, near Naples, is found in pumice-stone. The pumice-stone of Cotopaxi differs from that of the Zumbalica quarries ([457]): its fibres are short, not parallel, but confusedly bent. Magnesia-mica is not, however, peculiar to the pumice-stones, it is also found in the trachyte of Cotopaxi. ([458]) The volcano of Tungurahua appears to be entirely wanting in pumice. There is no trace of obsidian in the quarries of Zumbalica, but in the blocks thrown out by Cotopaxi, and lying near Mulalo, I have found, in very large masses, black obsidian, having a conchoidal fracture embedded in bluish grey weathered pearlstone. Specimens are preserved in the Royal Mineralogical Collection at Berlin. It would appear, therefore, that the quarries of pumice-stone 16 miles from the foot of Cotopaxi, which have been described above, are not at all related to that mountain in mineralogical constitution, and only stand towards it in the same

connection, which all the volcanoes of Pasto and Quito bear to the volcanic hearth of the equatorial Cordilleras, embracing an area of very many hundred square miles. Were these pumice-stones the centre and interior of a special crater of elevation, whose outer encircling ridge has been destroyed in the many revolutions which the earth's surface has undergone in these regions? or were they deposited horizontally, in apparent tranquillity, over fissures at the time of the first crumpling or folding of the earth's crust? For still greater difficulties attach to the supposition of their having been deposited as sediment from flows of water, as is often seen in volcanic masses of tufa, mixed with remains of plants and shells.

Similar questions are suggested by the great masses of pumice, at a distance from any volcanic elevation, which I found in the Cordillera of Pasto, between Mamendoy and the Cerro del Pulpito, near the Rio Mayo, 36 geographical miles north of the active volcano of Pasto. Leopold von Buch has also called attention to a similarly isolated outbreak of pumice, described by Meyen, in Chili, east of Valparaiso, near the village of Tollo, where it forms a hill about 300 feet high. The volcano of Maypo, which in its upheaval lifted up jurassic strata, is two entire days' journeys from this outbreak of pumice. ([459]) The Prussian Envoy at Washington, Friedrich von Gerolt, to whom we owe the first coloured geological map of Mexico, mentions pumice-stone being obtained from beneath the surface of the ground for building purposes, near Huichapa, 32 geographical miles south-east of Queretaro, at a distance from any volcano. ([460]) The geological investigator of

the Caucasus, Abich, is inclined, from his own observations, to regard the great eruption of pumice near the village of Tschegem, on the northern side of the central chain of Elbouruz, as an effect of action from fissures much more ancient than the elevation of that conical mountain, from which it is at a considerable distance.

If, according to the view which we have taken of volcanic activity, we regard the diminution of the earth's original temperature, by the radiation of its heat into space, as the original cause, and the cooling and contraction of the outer strata as the immediate effect, producing fractures and foldings in the outer strata, in which foldings some portions will be raised, and some portions depressed ([461]), it will follow that the number of recognisable volcanic frame-works (open cones and dome-shaped elevations), upheaved over fissures, should be regarded as the measure and evidence of the degree of this activity in different regions. Such computations have often been made in a very imperfect and unsatisfactory manner, and sometimes mounts of eruption and solfataras belonging to one and the same system, have been enumerated as distinct volcanoes. The large spaces in the interior of continents, which have hitherto remained closed to all scientific examination, have not been such great obstacles in the way of these inquiries as may have been commonly supposed; as, generally speaking, volcanoes are most often met with in islands, and in regions near the coast. In a numerical inquiry, which the state of our knowledge will not permit us to render complete, much may still be gained by our being able to assign an inferior limit, and to state, with probably considerable approximation, the number of

points at which, within historic periods, the fluid interior of the earth has remained in active intercourse with the atmosphere. Such activity manifests itself, most often simultaneously, by eruptions from volcanic mountains, by increasing heat and inflammability of thermal and naphtha springs, and in the increased extent of areas of commotion: phænomena which are all in intimate interconnection and mutual dependence. ([462]) Leopold von Buch has here again the great merit of having, in writings appended to his physical description of the Canary Islands, undertaken for the first time to embrace all the volcanic systems of the globe in a cosmical view, while employing the well-grounded distinction of central and linear systems of volcanoes. My own later, and therefore more complete, enumeration, undertaken on principles indicated above (pp. 243 and 265.) excluding, therefore, unopened domes, and mere cones of eruption, gives, as a probable limitary mere minimum number (nombre limite inférieur), a result which differs considerably from any previously stated.

The question has been repeatedly raised, whether in the parts of the earth's surface in which volcanoes are most numerous, and the reaction of the interior upon the solid crust of the earth most apparently active, the molten interior may not actually be nearer to the surface? Whatever be the mode adopted for determining the greatest mean thickness of the solid crust, whether the purely mathematical one supplied by theoretical astronomy ([463]), or the more simple one which is based on the law of increase of heat with increasing depth, and the melting point of rocks ([364]); still the problem presents a great number of, at present, indeterminate quan-

tities. We may cite as such the influence of enormous pressure on the fusibility, the very different heat-conducting power of different rocks, the remarkable diminution of the conducting power with great increase of temperature treated of by Forbes, the unequal depth of the bed of the ocean, and all the local accidents in the connection and character of the fissures which lead down to the fluid interior! If the greater frequency of volcanoes and the more frequent and active intercourse between the interior and the atmosphere in some regions of the earth, is to be explained by the greater proximity of the upper limit of the fluid interior to the surface, this proximity may itself depend either on the relative mean difference between the heights of the bed of the sea and the continent, or on the unequal vertical depth at which in different latitudes and longitudes the surface of the molten fluid mass is situated. But where does such a surface commence? are there not intermediate degrees between perfect rigidity and perfect fluidity? Transitional states, which have often come into discussion in controversies respecting the plasticity of some plutonic and volcanic rocks which have been raised to the surface, and respecting the movements of glaciers? Such intermediate states escape from mathematical consideration as much as does the state of the so-called fluid interior under an enormous pressure. If it be in itself not altogether probable that heat should everywhere continue to increase in arithmetical progression with increasing depth, so also there may occur local intervening disturbing causes, *e. g.* by subterranean basins, or hollows, in the solid mass, which may be from time to time partially filled *from below*, with fluid lava and

vapours resting upon it. (465) Such hollows were already made to play a part in the theory of decreasing central heat by the immortal author of the "Protogæa," "Postremò credibile est contrahentem se refrigeratione crustam *bullas* reliquisse, ingentes pro rei magnitudine, id est, sub vastis fornicibus *cavitates*." (466) The more improbable it is that the thickness of the already solidified crust of the earth should be the same in all regions, the more important is the consideration of the number and geographical position of the volcanoes which are or have been open within historic times. Such a view of the geography of volcanoes can only be perfected by often renewed attempts.

1. *Europe.*

Etna,	Ischia,
Volcano in the Liparis,	Vesuvius,
	Santorin,
Stromboli,	Lemnos,

All belong to the great basin of the Mediterranean Sea, but to its European, not its African shores: all these seven volcanoes are or have been active within historic times; the burning mountain Mosychlos in the island of Lemnos, which Homer terms the darling seat of Hephæstos, was only destroyed and sunk beneath the waves of the sea, together with the island of Chryse, by the action of earthquake shocks, subsequently to the period of the great Macedonian. (See Kosmos, Bd. i. S. 256 and 456, Anm. 9; Engl. ed. p. 230 and note 230; Ukert, Geogr. der Griechen und Römer, Th. ii. Abth. i. S. 198.) The great and, for almost 1900 years (from

186 B.C. to 1712), often repeated upheaving of the three vents in the middle of the Gulf of Santorin (partly enclosed by Thera, Therasia, and Aspronisi), has borne a striking similarity to the comparatively small phænomenon of the temporary formation of the islands called Graham, Julia, and Ferdinandea, between Sciacca and Pantellaria. On the peninsula of Methana, as has been so often remarked (Kosmos, Bd. i. S. 453, Bd. iv. Anm. 86 to S. 273; Engl. ed. vol. i. note 230, and vol. iv. note 310), there are visible traces of volcanic eruptions in the reddish brown trachyte which rises up out of the calcareous rock at Kaïmenochari and Kaïmeno (Curtius, Pelop. Bd. ii. S. 439.)

Of *prehistoric volcanoes*, with fresh traces of outpourings of lava from craters, we have — proceeding from north to south — the volcanoes of the Eifel (Mosenberg, Geroldstein), as the most northern; the great crater of elevation, in which Schemnitz is situated; Auvergne (Chaine des Puys, or Mont Dômes, le Cône du Cantal, les Monts Dore); Vivarais, in which the ancient lavas have broken forth out of gneiss (Coupe d'Aysac and the Cone of Montpezat); Velay, eruptions of scoriæ without any lavas; the Euganean Hills; the Alban Hills, Rocca Monfina and Vulturo, near Teano and Melfi; the extinct volcanoes near Olot and Castell Follitt in Catalonia ([469]); the group of islands called las Columbretes, near the coast of Valencia (the larger crescent-shaped island, Colubraria of the Romans, has on it Montcolibre, in 39° 54′ N. lat. according to Admiral Smyth, full of obsidian and cellular trachyte); the Greek island Nisyros, one of the Carpathian Sporades, quite circular in form, having in its centre, at a height of 2270 feet according

to Ross, a deep caldera, having an encircling ridge with a strongly detonating solfatara, from which have radiated streams of lava flowing into the sea, and now forming small promontories; this island furnished volcanic mill-stones in the time of Strabo. (Ross, Reisen auf den Griech. Inseln, Bd. ii. S. 69 and 72-78.) For the British Islands I may here refer, on account of their antiquity, to the remarkable effects of submarine volcanoes on the Lower Silurian strata (Llandilo flags), inasmuch as volcanic cellular fragments are imbedded in these strata; and, according to Sir Roderick Murchison's important observation, eruptive masses of trap even penetrate into the Lower Silurian strata in the Corndon Hills (Shropshire and Montgomeryshire) ([468]); the dyke phenomena of the island of Arran; and other places where there is evidence of the introgression of volcanic activity, but no traces of actual volcanoes have been found.

2. *Islands in the Atlantic.*

Volcano Esk on the island of Jan Mayen, ascended by the meritorious Scoresby, and named by him after his ship; height rather less than 1600 feet. An open but not burning summit crater; basalt, rich in pyroxene and trass.

South-west of the Esk volcano, near the north cape of Egg Island, another volcano, which, in April 1818, ejected ashes to a considerable height, at intervals of four months.

Beerenberg, 6872 feet high, in the broad north-eastern part of Jan Mayen, (71° 4′ N. lat.) is not known to be a volcano. ([469])

Volcanoes of Iceland: Oeräfa, Hecla, Rauda-Kamba, &c.

Volcano in the Island of Pico ([470]), one of the Azores: great eruption of lava from 1st of May to 5th of June 1800.

Peak of Teneriffe.

Volcano of Fogo ([471]), one of the Cape de Verde Islands.

Prehistoric volcanic activity.—This kind of volcanic activity is less definitely connected with particular centres in Iceland than in other places. If, with Sartorius von Waltershausen, we divide the volcanoes of Iceland into two classes, one of such as have had only a single eruption, and the other of such as have repeatedly poured forth streams of lava from the same principal fissure, then the first class will include Rauda-Kamba, Skapta, Ellidavatan, south-east of Reykiavik, &c.; while to the second class, which shows a more permanent individuality, belong the two highest volcanoes of Iceland, Oeräfa (fully 6,400 feet high), and Snaefiall, Hecla, &c. Snaefiall has not been in eruption within the memory of man; while Oeräfa is known for its dreadful eruptions in 1362 and 1727. (Sart. von Waltershausen, Phys. geogr. Skizze von Island S. 108 and 112.) In Madeira ([472]), the two highest mountains: the conical Pico Ruivo, 6059 feet high, and Pico de Torres, which is only a little lower, and which have their steep declivities covered with scoriaceous lavas, cannot be regarded as the central points of the former volcanic activity of the entire island, as at many other points, and, especially towards the coasts, orifices of eruption have been found, and even a large crater,

that of the Lagoa, near Machico. The lavas have been thickened by confluence, and cannot be traced far as separate currents. Remains of ancient dicotyledonous vegetation, and of ferns, which have been accurately examined by Charles Bunbury, are found buried in raised beds of volcanic tufa and mud, and sometimes covered by more recent basalts. Fernando de Noranha, 3° 50′ S. lat., and 2° 27′ east of Pernambuco, a group of very small islands: rocks of phonolite, containing hornblende; no crater, but vein-fissures, filled with trachyte and basaltic amygdaloid, traversing white beds of tufa. ([473]) Island of Ascension, its highest summit 2867 feet: basaltic lavas with more glassy felspar interspersed than olivine, and in well defined currents which can be traced to the trachytic cone of eruption. Light-coloured trachyte, often in a tufa-like state of disintegration, prevails in the interior, and in the south-east part of the island. The masses of scoriæ, which have been thrown out from the Green Mountain, contain imbedded angular fragments ([474]) in which there are syenites and granites; these fragments remind us of the lavas of Jorullo. To the west of the Green Mountain there is a large open crater. Volcanic bombs, partially hollow, sometimes of 10 or 11 inches diameter, lie scattered about in great numbers, as do also large masses of obsidian. St. Helena: the whole island is volcanic; in the interior, there are more feldspathic beds of lava; towards the sea-shore, basaltic rock, traversed by countless dikes, as in the Flagstaff Hill. Between Diana's Peak and Nest Lodge, in the central mountain range, there is "the mere wreck of a great crater" ([475]), full of scoriæ and cellular lava. The beds of lava are

not definitely circumscribed, and cannot, therefore, be traced as proper lava-currents of small breadth. Tristan da Cunha (37° 3′ S. lat., 11° 27′ W. long.), discovered by the Portuguese in 1506, a small circular island of 6 miles diameter, having for its centre a conical mountain, which Capt. Denham describes as being about 8,300 feet high, composed of volcanic rock. (Petermann's Geogr. Mittheilungen, 1855, No. III. S. 84.) South-east of Tristan da Cunha, in 53° S. lat., is the also volcanic Thompson's Island; and intermediate between them, in the same line, is Gough Island, also called Diego Alvarez. Deception Island, a narrow, ring-island, with a small opening (62° 55′ S. lat.); and Bridgman Island, b longing to the South Shetland group, are both volcanic; and amidst beds of ice, pumice, black ashes, and obsidian, perpetually send forth hot vapours. (Kendal in the Journal of the Geogr. Soc. vol. i. 1831, p. 62.) In February 1842, flames were seen to issue at once from thirteen points of the Ring of Deception Island. (Dana in U.S. Explor. Exped. vol. x. p. 548.) It is remarkable that while so many other islands in the Atlantic are volcanic, neither the small and quite flat Island of St. Paul (Peñedo de S. Pedro), one degree north of the equator (a very slightly laminated greenstone-schist, passing into serpentine) ([476]), nor the Falklands (with their quartzose clay-slates), nor South Georgia, nor Sandwich Land, appear to present any volcanic rocks. On the other hand, a region of the Atlantic about 0° 20′ south of the equator, and 19° 40′ west long. from Greenwich, is considered to be the seat of a submarine volcano ([477]). Krusenstern saw columns of black smoke rise from the sea in this neighbourhood,

(19th of May 1806), and the Asiatic Society in Calcutta, in 1836, had laid before them ashes collected on two different occasions at the same spot. According to very careful inquiries by Daussy, it appears that on five occasions, from 1747 to Krusenstern's voyage of circumnavigation,—and on seven occasions, from 1806 to 1836, —navigators within this volcanic region (as it is called in the recent fine American chart of Lieut. Samuel Lee, Track of the Surveying Brig Dolphin, 1854) have remarked strange heavings of the sea, and shocks to their vessels, which have been attributed to agitation of the bottom of the sea by earthquake movements. Yet very recently (Jan. 1852), in the Expedition of the Brig Dolphin, which was instructed to take soundings between the equator and 7 S. lat. and between 16 and 25 W. long., with reference to "Krusenstern's volcano," nothing remarkable was perceived, as had also been the case in Wilkes's Exploring Expedition.

3. *Africa.*

The volcano Mongo-ma Leba in the Cameroon mountains (N. lat. 4° 12′) west of the mouth of the river of the same name, in the Bight of Biafra, east of the Delta of the Quorra or Niger, according to Captain Allen, emitted a stream of lava in 1838. The line of direction of four lofty volcanic islands, Annabona, St. Thomas, Prince's Island, and Fernando Po, over a S.S.W. N.N.E. fissure, points to the Cameroon mountain which, according to Captain Owen and Lieutenant Boteler, reaches the great height of about 13,000 feet. [478]

A volcano? is believed to be a little to the west of the snow-covered mountain Keenia, in Eastern Africa, in about 1° 20′ S. latitude, found in 1849, by the missionary Krapf, near the sources of the Dana River, about 320 geographical miles north-west of the sea-coast near Mombas. In a parallel nearly 2° more southerly there is another snowy mountain, Kilimandjaro, discovered in 1847 by the missionary Rebmann, scarcely 200 miles from the same coast. Rather more to the west there is a third snowy mountain, Doengo Engai, which was seen by Captain Short. The knowledge of the existence of these mountains has resulted from courageous and perilous undertakings.

Proofs of *prehistoric volcanic activity* in the interior of this great continent, but which has been so little explored between the parallels of 7° N. and 12° S. latitude, (those of Adamowa and the water dividing Lubalo mountains,) are presented (according to Rüppell) by the country round Lake Tzana, in the kingdom of Gondar, as well as by the basaltic lavas, trachytes, and obsidians of Shoa, according to Rochet d'Héricourt; the specimens brought home by the last-named traveller have been examined by Dufrenoy, and found very analogous to those of the Cantal and Mont Dore. (Comptes Rendus, t. xxii. p. 806—810.) If the conical mountain Koldghi in Kordofan has not shown itself to be still active, yet the existence of black, porous, vitrified rocks there has been confirmed. ([479])

In Adamowa, south of the great Binue river, rise the isolated mountain-masses of Bagele and Alantika, which Dr. Barth, in his journey from Kuka to Jola, judged by their cone and dome-shaped form to be

probably trachytic mountains. Overweg, so early taken away from the natural sciences, found in the district of Gudscheba, examined by him west of Lake Tshad, according to Petermann's notices derived from his journals, columnar basaltic cones, rich in olivine, which have broken through the beds of red argillaceous sandstone in some cases, and of quartzose granite in others.

A remarkable phænomenon is presented by the paucity of still active volcanoes in this continent, whose coasts, which are tolerably well known to us, present so few indentations. May there be in the unknown regions of Central Africa, especially south of the equator, great basins of water analogous to Lake Uniamesi (previously called N'yasse by Dr. Cooley), on the shores of which volcanoes may rise like Demavend, near the Caspian? Hitherto no reports of such have reached us from any of the natives, who yet are great travellers.

4. *Asia.*

a. The Western and Central Portion.

Volcano of Demavend (480), burning, but according to the accounts of Olivier, Morier, and Taylor Thompson (1837), only moderately, and not smoking uninterruptedly.

Volcano of Medina (eruption of lava in 1276).

Volcano Djebel el Tir (Taer or Tehr): an island-mountain 895 feet high, in the Red Sea, between Loheia and Massaua.

Volcano Peschan: north of Kutsch in the great chain of the Thian-schan, or Celestial mountains, in the interior of Asia; eruptions of lava within a thoroughly

historical period, from the year 89 A.D. to the beginning of the seventh century.

Volcano Ho-tscheu, also sometimes called, in the very circumstantial Chinese descriptive geography, volcano of Turfan: 120 geographical miles from the great Solfatara of Urumtsi, near the east end of the Thian-schan towards Hami, where much very fine fruit is produced.

The volcano of Demavend, which rises to a height of more than 19000 feet, is about thirty miles from the south shore of the Caspian, in the province of Mazenderan; almost equidistant from Rescht and Asterabad, on the chain of the Hindu-Kho, which falls away rapidly towards Herat and Meschid on the west. In another work (Asie centrale, t. i. p. 124—129, t. iii. p. 433—435) I have shown that it is probable that the Hindu-Kho, from Chitral and Cafiristan, is a westerly continuation of the great chain of the Kuen-lun which bounds Thibet on the north, and at Tsunling crosses the Bolor mountains which run north and south. Demavend belongs to the Persian or Caspian Elburz or Elbourz; employing that term as the name of a mountain-system; not to be confounded with the Caucasian mountain summit, having a name of similar sound, situated $7\frac{1}{2}°$ more to the north, and $10°$ more to the west (now called Elburuz.) The word Elbourz is a disfigurement of Albordj, the world-mountain, which is connected with the very ancient cosmogony of the Zend-people.

I have said that in taking a general view of the direction of the mountain systems of Central Asia, we may regard the volcano of Demavend, as being nearly

the western extremity of the Kuen-lun; we may also, I think, regard with particular attention, as being at their easternmost extremity, another igneous phænomenon, whose existence was first made known by me (Asie centrale, t. ii. p. 427 and 483). In the important researches which my honoured friend and colleague in the Institute, Stanislas Julien, has undertaken, at my request, for the purpose of obtaining from the rich geographical sources of the old Chinese literature, information respecting the Bolor, the Kuen-lun, and the "starry-sea," he found in the great dictionary edited by the Emperor Yongtsching in the beginning of the eighteenth century, a description of the "perpetual flame" which issues forth from a cave in the hill Schinkhieu on the slope of the eastern part of the Kuen-lun. This phænomenon, the light of which is seen from a great distance, cannot well be called a volcano: it appears rather to be analogous to the Chimæra in Lycia, famous of old among the Greeks. It is a fountain of fire, a spring of gas, which the volcanic activity of the interior of the earth keeps always lighted (Kosmos, Bd. iv. S. 296, note 51; Eng. ed. p. 252 and note 375.)

Arabian writers say, but generally without assigning any particular year, that, in the middle ages, eruptions of lava took place at particular points on the south-west coast of Arabia, in the islands of Zobayr in the straits of Bab-el-Mandeb and at Aden (Wellsted, Travels in Arabia, vol. ii. p. 466—468), in Hadhramaut, in the straits of Ormuz, and in the western part of the Persian gulf;—always upon ground which had been the seat of volcanic activity since prehistoric times. The epoch of the eruption of a volcano at Medina

itself, $12\frac{1}{2}$ degrees north of the straits of Bab-el-Mandeb, has been found by Burckhardt in Samhudy's chronicle of that celebrated town. It corresponds to the 2nd of November 1276. But we also learn from Abulmahasen that an igneous eruption had taken place there in 1254, or twenty-two years earlier. (Compare Kosmos, Bd. i. S. 256, Eng. p. 234.) The island volcano, Djebel Tair, which was already recognised by Vincent as the "extinct once-burning island" of the Periplus Maris Erythræi, is still active and sends forth smoke, according to Botta, and according to information collected by Ehrenberg and Russegger (Reisen in Europa, Asien und Afrika, Bd. ii. Th. i. 1843, S. 54). Respecting the whole region round Bab-el-Mandeb, with the basaltic island of Perim; the crater-like encircling ridge within which the town of Aden is situated; the island of Seerah with streams of obsidian which are covered with pumice; and respecting the groups of islands of Zobayr and Farsan (the volcanic character of the latter was discovered by Ehrenberg in 1825), see the fine investigations of Ritter in his Erdkunde von Asien, Bd. viii. Abth. 1. S. 664—707, 889—891, and 1021—1034.

The volcanic range of the Thian-schan (Asie centrale, t. i. p. 201—203, t. ii. p. 7—61), a mountain system extending from west to east across Central Asia from the Altai to the Kuen-lun, was at one time an especial object of study to me, when to the little which Abel Remusat had obtained concerning it from the Japanese Encyclopedia, I was able to add the more important fragmentary notices discovered by Klaproth, Neumann, and Stanislas Julien (Asie centrale, t. ii. p. 39—50 and

335 to 364). The Thian-schan chain is more than eight times the length of the Pyrenees, if passing beyond the north and south chain of the Kusyurt-Bolor, which is traversed by it, we include the Asferah, which extends westward to the meridian of Samarcand, and in which, as in the Thian-schan, Ibn Haukal and Ibn al Vardi describe fountains of fire and luminous? clefts emitting sal-ammoniac. (See on Mount Botom, Asie centrale, t. ii. p. 16—20.) In the history of the dynasty of Thang it is expressly said, that, on one of the declivities of the Peschan, which perpetually sends forth fire and smoke, the stones burn, melt, and flow for several li "like liquid fat; the soft mass hardens as it cools." It is scarcely possible to indicate a current of lava more distinctly and characteristically. In the 49th book of the voluminous Geography of the Chinese Empire, which was printed at the expense of the government in Pekin from 1789 to 1804, the fire-mountains of the Thian-schan are described as still active. Their situation is so central that they are about equidistant (1520 geographical miles) from the nearest part of the Icy Sea and the mouths of the Indus and the Ganges; 1020 miles from the sea of Aral, and 172 and 208 miles from the salt lakes of Issikal and Balkasch. The flames which rise from the mountains of Turfan (Hotscheu) have also been mentioned by pilgrims to Mecca, who were officially questioned in 1835 at Bombay. (Journal of the Asiatic Soc. of Bengal, vol. iv. 1835, p. 657—664.) When will the volcanoes of Peschan and Turfan, Barkul and Hami, be visited by a scientifically qualified traveller, who might proceed from Gouldja on the Ili, which can be so easily reached?

The now better-known situation of the volcanic chain of the Thian-schan has very naturally led to the question, whether the mythical land of Gog and Magog, where perpetual fires are said to burn from the bottom of the River el Macher, may not be connected with the eruptions of Peschan or the volcano of Turfan? This Oriental myth, which belonged originally to the west side of the Caspian, the Pylæ Albaniæ, near Derbend, has migrated, as is so often the case with fables, and has travelled far to the eastward. Edrisi makes Salam el Terdjeman, interpreter to one of the Abasside caliphs, travel from Bagdad, in the first half of the ninth century, towards the Land of Darkness. Passing through the Steppe of the Baschkirs, he arrives at the snow-covered mountain Coccaïa, which is surrounded by the great wall of Magog (Madjoudj). Amédée Jaubert, to whom we owe important supplements to our knowledge of Nubian geography, has shown that the fires which burn on the declivity of the Coccaïa are not volcanic (Asie centrale, t. ii. p. 99). Edrisi places further to the south the Lake Tehama. I think I have shown the probability of Tehama being the great lake Balkasch, into which the Ili falls, and which is only 180 miles to the south. A century and a half after Edrisi, Marco Polo transferred the wall of Magog to the mountain of In-schan, east of the high plain of Gobi, towards the river Hoang-ho and the Chinese Wall, of which, as well as of the use of tea, the celebrated Venetian traveller, strangely enough, does not speak. The In-schan, the boundary of the dominions of Prester John, may be regarded as the eastern prolongation of the Thian-schan (Asie centr. t. ii. p. 92—104).

The two once lava-erupting conical mountains, the volcano Peschan and the Hotscheu of Turfan, were long erroneously regarded as forming one isolated volcanic group. They are almost 420 geographical miles apart, and are separated by a considerable mountain mass, Bogdo-Oola, covered by perpetual ice and snow. I think I have shown that, as in the Caucasus, the volcanic activity north and south of the long chain of the Thian-schan is in close geological connection with the limits of the circle of earthquake commotion, the hot springs, solfataras, fissures emitting sal-ammoniac, and beds of rock-salt.

As, according to my often expressed view, now fully participated in by the observer who is so thoroughly acquainted with the Caucasian mountain-system, Abich, the Caucasus itself is only to be regarded as belonging to the continuation of the fissure of the volcanic Thian-schan and Asferah, beyond the great Aralo-Caspian depression ([481]), we should here mention, by the side of the phænomena of the Thian-schan, as belonging to prehistoric epochs, the four extinct volcanoes; Elburuz 18,493 feet high, Ararat 17,112 feet, Kasbegk 16,532 feet, and Savalan 15,759 feet. ([482]) In elevation these volcanoes are intermediate between Cotopaxi and Mont Blanc. The Great Ararat (Agri-dagh), first ascended on the 27th September 1829 by Friedrich von Parrot, repeatedly in 1844 and 1845 by Abich, and lastly in 1850 by Colonel Chodzko, is dome-shaped like Chimborazo, and has two small elevations at the edge of the summit, but no summit-crater. The greatest, and probably the most recent, prehistoric lava eruptions of Ararat have all broken forth below the limit of per-

petual snow; the erupted substances are of two kinds; part being *trachytic* with glassy felspar, and interspersed pyrites very susceptible of weathering; and part *doleritic*, consisting chiefly of labradorite and augite, like the lavas of Etna; Abich regards the latter as, in this case, the more recent. The places from which the streams of lava have flowed (all of which, as already stated, are below the snow limit) are often marked by cones of eruption, and small craters surrounded by scoriæ (for example in the large grassy plain of Kip-Ghioll on the north-western declivity). Although the deep valley of St. James (a ravine which runs up to the summit of Ararat, and gives to its form a peculiar character, even when seen at a very great distance) presents much similarity to the Val del Bove of Etna, and renders visible the very interior structure of the upheaved dome, yet there is a striking difference, inasmuch as in St. James's Valley trachytic rock is found in mass, without lava currents, or beds of scoriæ or of rapilli. ([483]) The Greater and the Lesser Ararat, the first of which is, according to the excellent geodesical operations of Vasili Fedorow, 3′ 4″ to the north and 6′ 42″ to the west of the latter, rise on the southern edge of the great plain through which the Araxes rolls in a wide sweep. They both stand on the same elliptically shaped volcanic plateau, whose major axis is directed from south-east to north-west. Kasbegk and Tschegem are also without summit-craters, although the former has sent forth great eruptions in a northerly direction (towards Wladicaucas). The greatest of all these extinct volcanoes, the trachytic cone of Elburuz, which has been upheaved from the schistose, talcose, dioritic, and graniti-

ferous mountains of the valley of the Backsan River, has a crater-lake. Similar crater-lakes are found in the rough highland of Kely, and lava currents can be seen to have flowed from them between cones of eruption. Here, as in the Cordilleras of Quito, the basalts are widely separated from the trachyte systems; they only begin twenty-four and thirty-two miles south of the Elburuz chain, and of Tschegem, on the upper valley of the Phasis or Rhion.

β. The North-Eastern Part of Asia.

(Peninsula of Kamtschatka.)

The Peninsula of Kamtschatka, from Cape Lopatka (according to Krusenstern in 51° 3 N. lat.) northward to Cape Ukinsk, belongs to the same category as the Island of Java, Chili, and Central America, these being the regions on the earth's surface where the greatest number of volcanoes, and, moreover, the greatest number of still active volcanoes are congregated together on a comparatively small area. In Kamtschatka fourteen are enumerated in a length of 420 geographical miles. For Central America, I find, in 680 such miles (from the volcano of Soconusco to Turrialva in Costa Rica), twenty-nine volcanoes, of which eighteen are burning; for Peru and Bolivia in 420 miles (from the volcano Chacani to that of San Pedro de Atacama), fourteen volcanoes, of which three are at present active; for Chili, in 960 miles (from Volcan de Coquimbo to V. de San Clemente), twenty-four volcanoes, of which thirteen are known to have been active within historic

times. Our knowledge of the volcanoes of Kamtschatka, in respect to form, and exactly determined geographical position and elevation, has received admirable enlargement in modern times, through the exertions of Krusenstern, Horner, Hofmann, Lenz, Lütke, Postels, Beechey, and above all Adolph Erman. The peninsula is intersected lengthways by two parallel chains, in the easternmost of which the volcanoes are chiefly or wholly situated. The highest of these attain elevations of from 10,500 to 14,800 French feet (11,190 to 15,773 English feet). They succeed each other in order, as follows: proceeding from south to north.

The Opalinski Volcano (Peak Koscheleff of Admiral Krusenstern), lat. 51° 21′: according to Captain Chwostow, its elevation is almost equal to that of the Peak of Teneriffe, and it was exceedingly active at the end of the 18th century.

Hodutka Sopka (51° 35′ lat.). Between this mountain and the last there is an unnamed volcanic cone (51° 32′), which, however, like Hodutka, appears, according to Postets, to be extinct.

Poworotnaja Sopka (52° 22′ lat.), according to Captain Beechey 7931 feet high (Erman's Reise, Bd. iii. S. 253; Leop. von Buch, Iles Can. p. 447).

Assatschinskaja Sopka (52° 2′ N. lat.); great eruptions of ashes, especially in 1828.

Wiljutschinsk Volcano (lat. 52° 52′): according to Captain Beechey 7373 feet high, according to Admiral Lütke 6746 feet; only twenty geographical miles from the port of St. Peter and St. Paul, beyond the bay of Torinsk.

Awatschinskaja, or Gorelaja Sopka (lat. 53° 17′),

height, according to Erman, 8910 feet; first ascended in the expedition of La Perouse, in 1787, by Mongez and Bernizet; and subsequently by my dear friend and Siberian travelling companion, Ernst Hofmann (July 1824, in Kotzebue's Voyage of Circumnavigation); by Postels and Lenz in Admiral Lütke's expedition in 1828; and by Erman in September 1829. Erman made the important geological observation that the trachyte at its upheaval had broken through schist and graywacke (a Silurian rock). This still smoking volcano had a dreadful eruption in October 1837, having previously had a much slighter one in April 1828. Postels in Lütke's Voyage, t. iii. p. 67—84: and Erman, Reise, hist. Bericht, Bd. iii. S. 494, and 534—540.

Quite near to the Awatscha Volcano (see note 345 of the present volume) there is Koriatskaja or Strjeloschnaja Sopka (lat. 53° 19′), height 11,210 feet according to Lütke, t. iii. p. 84; rich in obsidian, which the people of the country continued, so late as the last century, to use as the Mexicans, and, at a very early period of their history, the Greeks had done, for arrow-points.

Jupanowa Sopka: lat., according to Erman's determination (Reise, Bd. iii. S. 469), 53° 32′. The summit is rather flattish; and Erman's remark upon it is, "that this Sopka, from the smoke which it emits, and the subterranean noises which are heard, has always been compared to the great volcano of Schiwelutsch, and reckoned among undoubted burning mountains." Its height was measured from the sea by Lütke, who made it 9055 feet.

Kronotskaja Sopka, 10,609 feet, on the lake of the same name, lat. 54° 8′; a smoking crater at the summit

of a very pointed conical mountain. (Lütke, Voyage, t. iii. p. 85.)

Schiwelutsch, twenty miles southeast of Jelowka, was almost unknown before it was visited and examined by Erman, from whom we now possess an excellent account of it (Reise, Bd. iii. S. 261—317, and Phys. Beob. Bd. i. S. 400—403): its northern point is in lat. 56° 40′ and its height 10,544 feet; southern point lat. 56° 39′, height 8793 feet. When Erman ascended Schiwelutsch in September 1829, he found it smoking strongly. Great eruptions took place in 1739, and between 1790 and 1810, the latter having been not of flowing liquid lava, but of loose volcanic rocks. According to C. von Dittmar, the northernmost summit fell in on the night of 17–18 February 1854, after which there followed an eruption of long continuance, which, possibly, has not yet ceased, accompanied by actual streams of lava.

Tolbatschinskaja Sopka: emits great outbursts of smoke, and has, in former times, often varied the place of the eruption-orifices, from which ashes have been ejected; according to Erman, lat. 55° 51′, and height 8313 feet.

Uschinskaja Sopka: nearly connected with the Kliutschewsk volcano, lat. 56° 0′, height (11,000 French) 11,723 English feet (von Buch, Can. S. 452; Landgrebe, Vulkane, Bd. i. S. 375.)

Kliutschewskaja Sopka (lat. 56° 4′): the highest and most active of all the volcanoes in this peninsula, has been thoroughly examined by Erman, both geologically and hypsometrically. According to the accounts of Kraschenikoff, it had great igneous eruptions from 1726 to 1731, and also in 1767 and 1795. In 1829, Erman, in his

dangerous ascent of the volcano, was himself an eyewitness, on the 11th of September, of the eruption of glowing stones, ashes, and vapours from the summit, while, far below, a considerable stream of lava poured itself forth from a fissure on the western declivity. Here, also, the lava is rich in obsidian. According to Erman (Beob. Bd. i. S. 400—403, and 419), the latitude of the volcano is 56° 4′, and its height, in September 1829, was very exactly 15,763 feet. On the other hand, in August 1828, Admiral Lütke, by angles of altitude taken from the sea at the distance of forty nautical miles, made it 16,500 feet (16,498). (Voyage, t. iii. p. 86; Landgrebe, Vulkane, Bd. i. S. 375—386.) This measurement, and the comparison of the excellent outline drawings of Baron von Kittliz, who accompanied Lütke's expedition in the Seniavin, with what Erman himself observed in September 1829, led the latter to believe that, in this short interval of thirteen months, great changes had taken place in the shape and height of the summit. He says (Reise, Bd. iii. S. 359), "we can scarcely be much in error if we assume the height of the summit in August 1828, to have been 250 French feet (266 English) higher than in September 1829; making the height, at the earlier epoch (in round numbers) 16,030 feet." On Vesuvius, taking as my basis Saussure's barometric measurement of the Rocca del Palo (the highest northern edge of the crater) in 1773, I found, by my own measurements, that in 1805 — therefore, in an interval of thirty-two years — this edge had sunk thirty-eight and one third feet; but that, from 1773 to 1822, or in forty-nine years, it had gained (apparently?) 102 feet. (Ansichten der Natur, 1849, Bd. ii. S. 290.) In 1822,

Monticelli and Covelli found for the Rocca del Palo 3990 feet, and I found nearly 4022 feet. I assumed as the most satisfactory final result for that time 3997 feet. In the spring of 1855, therefore, thirty-three years later, the fine barometrical measurements of the Olmutz astronomer, Julius Schmidt, again gave 3990 feet. (Neue Bestimm. am Vesuv., 1856, S. 1, 16, and 33.) How much of these differences is due to error of observation, barometric formulæ, and casual circumstances incidental to the method? Such investigations could be carried on more extensively and securely, if, instead of often repeated complete trigonometrical operations, or, in the case of accessible summits, of the more easily applied, but less satisfactory, barometric method, it were arranged simply to take, at desirable intervals, say twenty-five or fifty years, angles of altitude of the crater margin from some definite and easily identified spot, but making those angles exact to fractions of seconds. On account of the influence of terrestrial refraction, I would advise that, at each normal epoch, the mean of observations at several different hours and on three different days should be obtained. In order to have not merely the general result of increase or diminution, but also the absolute amount of change expressed in feet, it would suffice to determine, once for all, the distance of the point of observation. What a rich source of knowledge, founded on experience extending over more than a century, respecting the colossal volcanoes of Quito, would now be open to us, if, in addition to the sufficiently exact measurements left to us by Bouguer and La Condamine, those distinguished men had furnished us with the knowledge of exact spots, per-

manently marked, as the sites from which the angles of altitude of the respective summits had been taken? According to C. von Dittmar, after its eruption in 1841, Kliutschewsk was completely at rest until its reawakening in 1853, when it sent forth lava; but the falling in of the summit interrupted its renewed activity. (Bulletin de la Classe physico-mathem. de l'Acad. des Sc. de St. Pétersbourg, t. xiv. 1856, p. 246.)

There are yet four other volcanoes, mentioned in part by Admiral Lütke and in part by Postels, — Apalsk, which is still smoking, to the south-east of the village of Bolscheretski; Schischapinskaja Sopka (lat. 55° 11′); the conical Krestowsk (lat. 56° 4′), near the Kluitschewsk group; and Uschkowsk; — which I have not included in the preceding list, for want of more exact determinations. The central mountains of the peninsula, especially in the Baidar plains, in lat. 57° 20′, on the east of Sedanka, present (as if the plain were "the floor of a very ancient crater of about a league in diameter") the geologically remarkable phænomenon of lava and scoriæ, which have been poured forth from a brick-red volcanic rock, full of bubbles, which has itself broken forth through fissures in the earth, all at a considerable distance from any upheaved conical volcanoes of regular structure (Erman, Reise, Bd. iii. S. 221, 228, and 273; von Buch, Îles Canaries, p. 454). There is here a striking analogy to the circumstances which I have developed in detail above (p. 304), respecting the Malpais and problematical fields of rocky fragments in the Mexican highlands.

5. *East Asiatic Islands.*

From Torres Strait, which in 10° S. lat. divides New Guinea from Australia, and from the smoking volcanoes of Flores to the north-easternmost Aleutian Islands in 55° N. lat., there extends an island world, which is for the greater part volcanic, and which, when regarded in a general geological point of view by reason of its genetical connection, cannot very easily be separated into single groups, and of which the area widens considerably towards the south. Beginning in the north and proceeding from the American peninsula Alaska, we see the bow-shaped curvature of the range of Aleutian Islands ([484]), uniting, through the island of Attu which is near Copper and Bering's Islands, the old and the new continent; and, as it were, enclosing Bering's sea by a boundary towards the south. If we, further, proceed southwards from Cape Lopatka, the extremity of the peninsula of Kamtschatka, we have first the Kurile Islands, forming the eastern boundary of the sea of Saghalin or Ochotsk, which La Perouse rendered celebrated; next Jezo, which perhaps was once connected with the southern point of the island of Krafto ([485]) (Saghalin or Tschoka); and lastly, beyond the narrow straits of Tsugar, the three islands which form the Japanese empire (Nippon, Sikok, and Kiusiu, lying, according to Siebold's excellent map, between 41° 32′ and 30° 18′ N. latitude). From the volcano of Kliutschewsk, the northernmost one on the east coast of the Kamtschatkan peninsula, to the southernmost Japanese island-volcano of Iwoga-Sima in the strait of Van Die-

men, explored by Krusenstern, the direction in which the igneous activity manifests itself from the fissured crust of the globe is exactly from north-east to south-west. This direction is maintained through the island Jakuno-Sima, on which a conical mountain rises to the height of 5840 feet, separating the two straits of Van Diemen and Colnet; through Siebold's Linschote Archipelago; through Captain's Basil Hall's Sulphur Island (Lung-Huang-Schan); and through the small groups of Lieu-Khiew and Madjiko-Sima, which latter approaches within 92 geographical miles of the great island off the Chinese coast, Formosa (Thay-wan).

Here, at or near Formosa, in 25° and 26° N. lat., we may recognise the important point at which, instead of the north-east and south-west lines of elevation, those of a north and south direction commence, and prevail almost to the parallels of 5° or 6° S. lat. These N.—S. lines may be traced in Formosa and the Philippines (Luzon and Mindanao), through fully twenty degrees of latitude; cutting off, as it were, the coasts on either or on both sides; as for example, the east coast of the large island of Borneo, which is connected with Mindanao by the Solo Archipelago, and with Mindoro by the long narrow island of Palawan; and the western portion of Celebes with its strangely varied outline, and Gilolo; and (which is especially remarkable) appearing in the longitudinal fissure, over which, 1400 geographical miles east of the group of the Philippines and in the same latitude, the series of volcanic and coral-islands of the Marianas or Ladrones has been elevated. Its general direction is N. 10° E. ([486])

As we have marked the parallel of the coal-containing

island of Formosa as the turning point where the Kurile N.E.S.—W. direction is followed by a N.—S. one, so we may, in like manner, point to a new fissure-system as commencing to the south of Celebes and Borneo whose southern coast is cut east and west. The greater and lesser Sunda islands from Timor-Laut to West-Bali follow for the most part the mean parallel of 8° S. lat., through eighteen degrees of longitude. In the west part of Java the middle axis already turns rather more towards the north, running almost E.S.E.—W.N.W., but from the Straits of Sunda to the southernmost of the Nicobars the direction is S.E.—N.W. The entire volcanic fissure of elevation (E.—W. and S.E.—N.W.) has, according to this, an extent of about 2700 geographical miles, or eleven times the length of the Pyrenees; of the whole distance, if we disregard the slight deviation in Java towards the north, 1620 miles belong to the east and west, and 1080 to the south-east and north-west direction.

In this manner, geological considerations on form and arrangement conduct us uninterruptedly through the islands of the eastern coast of Asia, over the enormous space of 68 degrees of latitude, from the Aleutian islands and the northern sea of Bering to the Moluccas and the greater and lesser Sunda Isles. It is especially in the zone comprised between 5° N. and 10° S. latitude that the most abundant variety of configuration of land has been developed. The directions of the lines of outburst or elevation of the larger parts are most frequently seen repeated in a remarkable manner in neighbouring small ones. Thus, near the south coast of Sumatra, we have a long row of islands parallel to it. We may

remark in the small phænomenon of veins of ore the same kind of agreement as in the great one of lines of mountains, or of islands, extending over entire continents or extensive regions of the globe. Secondary veins having the same "strike" as the principal one, and accompanying or secondary chains of mountains ("chaines accompagnantes"), are often found at considerable distances; they point to the same causes and to the same directions of the form-giving agency in the folding or wrinkling of the earth's crust. The conflict of forces in the simultaneous opening of fissures in opposite directions appears to produce now and then extraordinary juxtapositions of form; as in the complicated outlines of Celebes and Gilolo.

Having thus indicated the inherent geological connection of the eastern and southern Asiatic islands, we will in order not to depart from the old, somewhat arbitrary, geographical divisions and nomenclature, take the southern limit of the East-Asiatic chain of islands at the point where near Formosa the direction turns or passes, as already stated, from N.E.—S.W. to N.—S., in the 24th degree of north latitude. The enumeration is again made from north to south; beginning with the easternmost, rather American than Asiatic, Aleutian Islands.

The Aleutian islands, rich in volcanoes, comprise, proceeding from east to west; the Fox islands, among which are the largest of the entire series Unimak, Unalaschka, and Umnak; the Andrejanowski islands, amongst which the most celebrated are Atcha with three smoking volcanoes, and the island of the great volcano of Tanaga, which has been drawn by Sauer; the Rat

islands and the Blynie islands, which stand somewhat apart; amongst these Attu forms, as we have already said, the transitional link with the Asiatic "Commandeur group" (Copper and Bering's Islands). There appears to be but little foundation for the often repeated statement, that the line of continental volcanoes in the peninsula of Kamtschatka, directed from N.N.E. to S.S.W., only begins at the place where the volcanic elevation fissure of the Aleutian islands, passing under the sea, intersects the peninsula; thus representing the Aleutian fissure as a channel of conduction. According to Lütke's map of Bering's Sea, the island of Attu, the westernmost extremity of the Aleutian Islands, is in 52° 46′ lat., and the non-volcanic Copper and Bering's islands are in 54° 30′ and 55° 20′, while the line of Kamtschatkan volcanoes commences in 56° 40′ with the great volcano of Schiwelutsch, west of Cape Stolbowoy. The direction of the eruptive fissures is also very different, almost opposite. The loftiest of the Aleutian volcanoes, that in Unimak, is, according to Lütke, 8076 feet high. Near to the north point of Umnak, in May 1796, the island of Agaschagokh (or Sanctus Johannes Theologus) was upheaved from the sea under very remarkable circumstances, which are extremely well described in Kotzebue's Voyage of Discovery (Bd. ii. S. 106); and it continued burning for almost eight years. According to an account communicated by Krusenstern, it was, in 1819, almost 16 geographical miles in circumference, and still upwards of 2200 feet high. On the island of Unalaschka, the relations assigned by the ingenious Chamisso of the trachyte containing much hornblende of the volcano Matuschkin (5474 feet high) to the black porphyry (?) and

adjacent granite, deserve to be examined by an observer well acquainted with modern geological science, and the mineralogical composition of the rocks to be accurately investigated. Of the two islands of the Pribytow group, which stand a little apart by themselves in Bering's sea, St. Paul's is entirely volcanic with much lava and pumice; although, on the other hand, St. George's only contains granite and gneiss.

According to the most complete accounts which we at present possess, the range of the Aleutian Islands, 960 miles long, appears to contain upwards of 34 volcanoes, most of which have been active within recent historic times. Thus, we have here (within 54° and 60° N. lat., and 160° to 196° W. long.) a strip of the whole sea bottom between two great continents in a state of constantly alternating, formative and destructive activity. Here, as in the Azores, in the course of thousands of years many islands may have been elevated to near the surface of the sea, yet without having actually risen above it, and many may long since have appeared and have subsided again, either wholly or partially unobserved. For the migration and intermixture of races and people, the Aleutian Islands offer a route 13 or 14 degrees south of that by Bering Strait, by which the Tschuktsches seem to have passed from America to Asia, and even to beyond the Anadyr River.

The range of the Kurile Islands, extending from the extreme point of Kamtschatka to Cape Broughton (the north-easternmost promontory of Jezo), a length of 720 geographical miles, has 8 or 10 volcanoes, most of which are still burning. The northernmost of these in the island Alaid is known for its great eruptions

in 1770 and 1793, and its height would appear to be well-deserving of exact measurement, being estimated at between 12,000 and 15,000 feet. The far lower peak Sarytschew (4505 feet, according to Horner) in Mataua, and the southernmost Japanese Kuriles, Urup, Jetorop and Kunasiri have also shown themselves to be still very active volcanoes.

Next in our volcanic series follow Jezo and the three great Islands of Japan, upon which the celebrated traveller Herr von Siebold has kindly communicated to me a very great and important notice, for employment in the Cosmos. It will rectify and complete the accounts taken from the great Japanese Encyclopedia in my Fragmens de Géologie et de Climatologie Asiatiques (t. 1, p. 217—234), and Asie centrale (t. 11, p. 540—552).

The large, and in its northern portion very square-shaped, island of Jezo ($41\frac{1}{2}°$ to $45\frac{1}{2}°$ lat.), divided by the Sangar or Tsugar Strait from Nippon, and by the Strait of La Perouse from Krafto (or Karafuto), bounds by its north-easternmost cape the range of the Kuriles; but not far from the north-westernmost point, Cape Romanzow, which advances a degree and a half further to the north on the Strait of La Perouse, there is in 45° 11′ lat. the volcanic Pic de Langle (5350 feet high), on the small island of Risiri. Jezo itself appears to be intersected by a range of volcanoes running from Broughton's southern Volcano bay towards the northern cape; and this is the more deserving of attention, because on the narrow island of Krafto, which may almost be regarded as a continuation of Jezo, the naturalist of La Perouse's expedition found in the Baie de Castries red

porous lavas and fields of scoriæ. In Jezo itself, Siebold counts seventeen conical mountains, of which the greater part appear to be extinct volcanoes. Kiaka, called by the Japanese Usuga-Take, or the "Mortar-mountain," from a deeply sunken crater, and Kajo-hori, both appear to be still burning. (Commodore Perry saw two volcanoes at the harbour of Endermo, lat. 42° 17′.) The lofty range (Krusenstern's conical mount Pallas) is in the middle of the Island of Jezo, in about 44° lat., and about E.N.E. of Strogonow Bay.

"The historians of Japan mention only six volcanoes as having been active after or before our era, two in the island of Nippon, and four in that of Kiusiu. The volcanoes of Kiusiu, the island nearest to the Corean peninsula, are, taking them according to their geographical position from south to north: (1) Mitake volcano, on the little island Sayura-Sima, in the bay of Kagosima, which is open towards the south, in the province of Satsuma (lat. 31° 33′, long. 130° 43′ E.); (2) Volcano Kirisima, in the district of Naka, and in the province of Fiuga (lat. 31° 45′); (3) Asojama, in the district Aso, province Figo (lat. 32° 45′); (4) Wunzen, in the peninsula of Simabora, in the district Takaku (lat. 32° 44′). The height of the last-named volcano amounts, according to barometric measurement, to only 4110 feet, only about a hundred feet higher than Vesuvius (Rocca del Palo). Its most violent eruption, historically known to us, was that of February 1793. The volcanoes Wunzen and Asojama are both east-south-east of Nangasaki.

"The volcanoes of the great island of Nippon are, again beginning with the south:—(1) Fusijama, scarcely

sixteen geographical miles from the south coast, in the district of Fusi, province Suruga (lat. 35° 18′, long. 138° 37′ E.). Its height, measured like that of the above-named volcano of Wunzen, in the island of Kiusiu, by young Japanese observers trained by Siebold, reaches 12,443 feet; almost 300 feet higher, therefore, than the Peak of Teneriffe, with which Kämpfer had already compared it. (Wilhelm Heine, Reise nach Japan, 1856, Bd. ii. S. 4.) The upheaval of this mountain took place in the fifth year of the reign of Mikado VI., (286 B.C.), as described in the following (geologically remarkable) terms, 'In the country about Omi, a considerable tract of land sank down, a lake was formed, and the volcano of Fusi rose to view.' The historically known most violent eruptions were those of 799, 800, 863, 937, 1032, 1083, and 1707 A.D., since which last date the mountain has been in repose. (2) Volcano Asamajama; the most central of the active volcanoes in the interior of the country; distant 80 geographical miles from the S.S.E., and 52 from the N.N.W. coasts respectively; in the district Saku, province Sinano, lat. 36° 22′, long. 138° 40′ E.; therefore between the meridians of the two principal towns Mijako and Jedo. Asamajama had an eruption as early as in the year 864 (contemporaneously, therefore, with Fusijama). It had a very violent and destructive eruption in July 1783, since which time it has been in permanent activity.

"In addition to these volcanoes, European navigators have observed two small islands with smoking craters, viz.: — (3) the little island Iwôgasima or Iwôsima (sima signifies island, and iwô sulphur; ga is a mere affix of

the nominative), Île du Volcan of Krusenstern, south of Kiusiu in Van Diemen Strait, in 30° 43′ lat. and 130° 20′ E. long., only 54 English miles from the above-named volcano of Mitake, height 2366 feet. This small island is mentioned by Linschote in 1596, who says; 'it has a volcano, which is a sulphur or a burning mountain.' We find it also in the oldest Dutch maps with the name 'Vulcanus.' (Fr. von Siebold, Atlas vom Jap. Reiche, tab. XI.) Krusenstern saw it smoking in 1804, as did Captain Blake in 1838, and Guérin and de la Roche Poncié in 1846. The height of the cone, according to the last-mentioned navigator, is 2363 feet. The small rocky island which Landgrebe mentions as a volcano, in the Naturgeschichte der Vulkane (Bd. 1, S. 355), according to Kämpfer not far from Firator (Firando), is indisputably Iwôsima; for the group to which Iwôsima belongs is called Kiusiu ku sima, *i.e.* the nine islands of Kiusiu, not the 99 islands. There is such a group near Firato, north of Nagasaki, and nowhere else in Japan. (4) The island Ohosima (Barnevelt's Islands, Krusenstern's Île de Vries); it is reckoned as belonging to the province of Idsu in Nippon, and lies in front of the Bay of Wodawara, in 34° 42′ N. lat. and 139° 26′ E. long. Broughton in 1797 saw smoke rise from the crater, a short time before a violent eruption had taken place. A range of volcanic islets runs southward from Ohosima to Fatsi sjô (33° 6′ N.), and is continued to the Bonin Islands (26° 30′ N. and 142° 5′ E.), which, according to Postels (Lütke, Voyage autour du Monde dans les années 1826—29, t. iii. p. 117), are also volcanic and subject to very violent earthquakes.

"These then are the eight historically active volcanoes

of Japan proper, in and near the islands Kiusiu and Nippon. But besides these there is a range of conical mountains, some of which, characterised by very clearly marked and often deeply depressed craters, appear to be long extinct volcanoes: this is the case with the conical mountain Kaimon, Krusenstern's Pic Horner, in the most southern part of Kiusiu, on the shore of Van Diemen Strait, in the province of Satsum (lat. 31° 9′), scarcely 24 geographical miles S.S.W. from the active volcano of Mitake; and so also with Kofusi or the little Fusi in Sikok, on the small island of Kutsunasima (province Ijo), lat. 33° 45′, on the east shore of the great strait Suwo Nada or van der Capellen, which separates the three great portions of the Japanese empire, Kiusiu, Sikok, and Nippon. On the last, the principal island, there are enumerated, proceeding from south-west to north-east, nine such conical mountains, probably trachytic, amongst which the most remarkable is the Sirajama (White mountain) in the province Kasa (lat. 36° 5′), which, as well as the Tsjo kaisan, in the prcvince Dewa (lat. 39° 10′), is estimated to be higher than the lofty southern volcano Fusijama, more than 12,300 feet high. Between Sirajama and Tsjo kaisan there is Jakijama (the flame mountain) in the province of Getsigo, in lat. 36° 53′. The two northernmost conical mountains on the Tsugar Straits, in sight of the great island of Jezo, are: (1) Jwakijama, which Krusenstern, whose services to the knowledge of Japanese geography are deserving of enduring remembrance, called Pic Tilesius (lat. 40° 42′); and (2) Jakejama (burning mountain, lat. 41° 20′) in Nambu, on the north-easternmost end of Nippon, which has had fiery eruptions since the earliest times."

On the side of the continent, in the adjacent peninsula of Corea or Korai (it is almost united to Kiusiu in lat. 34° and 34½° by the islands Tsusima and Iki), notwithstanding its resemblance in form to Kamtschatka, we as yet know of no volcanoes. The volcanic activity appears to have been confined to the islands near to it. Thus, the island-volcano Tsinmura, which the Chinese call Tanlo, rose from the sea in the year 1007. A learned man, Tien-kong-tschi, was sent to see and describe the phænomenon, and to make a drawing of it ([487]). On the island Se-he-sure (Quelpaerts of the Dutch), the mountains show everywhere a volcanic conical outline. The central mountain, according to La Perouse and Broughton, reaches a height of 6000 French feet (6395 feet.) How many more volcanic manifestations may there not still be to discover in the western archipelago, where the king of the Corea takes the title of the king of 10,000 isles!

From Peak Horner (Kaimon-ga-take) at the south-western point of Kiusiu there runs a bow-shaped range of small volcanic islands, the opening of the bow being towards the west, and it comprises between the straits of Van Diemen and Colnett, Jakunosima and Tanegasima: and then passing south of Colnett strait into the Linschote group of Siebold ([488]) (Archipel Cecille of Captain Guérin, which extends to the parallel of 29°) it includes Suwasesima, Captain Belcher's Volcano island in 29° 39′ N. and 129° 43′ E.; height 2803 feet, according to de la Roche Poncié; then Basil Hall's Sulphur island, Torisima or Bird island of the Japanese, Lung-hoang-schan of Father Gaubil, 27° 51′ N. and 128° 61′ E., according to the determination of Captain de la

Roche Poncié in 1848. As it is also called Iwôsima, care must be taken not to confound it with the more northern island of the same name in the Strait of Van Diemen. It has been extremely well described by Captain Basil Hall. Between 26° and 27° of latitude follow the Loo Choo islands, of which Klaproth had given a special map so early as 1824; and more to the south-west the little archipelago of Madschikosima which approaches near to the great island of Formosa, and is regarded by me as the termination of the East Asiatic islands. In lat. 24° near the east coast of Formosa, in October 1853, Lieutenant Boyle observed a great volcanic eruption in the sea. (Commodore Perry, Exped. to Japan, vol. i. p. 500.) In the Bonin islands (Buna-sima of the Japanese, lat. $26\frac{1}{2}$° to $27\frac{3}{4}$° N., 142° 17′ E.), Peel's island has several craters with sulphur and scoriæ, which appear not to have been long extinct. (Perry, vol. i. p. 200 and 209.)

6. *South Asiatic Islands.*

We comprise under this head Formosa (Thaywan), the Philippines, the Sunda Isles, and the Moluccas. The volcanoes of Formosa were first made known to us by Klaproth from Chinese sources, which always give such circumstantial descriptions of natural phænomena. (489) They are four in number, one of which, Tschykang, Red Mountain, has a crater lake of hot water, and has had great igneous eruptions. The small Baschi islands, and the Babuyans which so late as 1831, according to Mayen, had a vehement fiery eruption, connect Formosa with the Philippines, the smallest and most broken of which

are the principal volcanic sites. Leopold von Buch enumerates in the Philippines nineteen lofty isolated conical mountains, all called in the country "Volcanes," but of which some probably are closed trachytic domes. Dana thinks that in the southern part of Luzon there are now only two active volcanoes, Taal in the Laguna de Bongbong or Bombon, with an encircling ridge enclosing a second Laguna (see above, p. 242.); and in the south part of the peninsula of Camarines the volcano of Albay or Mayon, which the natives call Isaroe; it is about 3200 feet high, and had great eruptions in the years 1800 and 1814. In the northern part of Luzon granite and mica slate, and even sedimentary formations and coal, are diffused. ([490])

The long extended group of the Sulu or Solo islands, probably fully a hundred in number, connecting Mindanao with Borneo, is partly volcanic and partly intersected by coral reefs. Isolated unopened trachytic conical peaks are, indeed, often called "Volcanes" by the Spaniards.

Dr. Junghuhn, after having carefully passed in review all those islands which are to the south of the fifth parallel of north latitude (south, therefore, of the Philippines), and between the meridians of the Nicobars and the north-west of New Guinea, states as the result that "in a wreath of islands surrounding the great and almost continental island of Borneo there are 109 lofty fire-emitting mountains and ten mud-volcanoes." This is by no approximate estimate but by actual enumeration.

In Borneo itself, the Giava Maggiore of Marco Polo ([491]), we have as yet no certain knowledge of any

active volcano; we are indeed only acquainted with some narrow strips of coast (on the north side as far as the little island of Labuan and Cape Balambangan, on the west coast to the mouth of the Pontianak, and on the south-easternmost point the district of Banjermas-Sing on account of its gold, diamond, and platina washings): nor is the loftiest mountain of the whole island, (perhaps the loftiest in any of the South Asiatic islands,) Kina Bailu, with its two summits, of which the northern is only about thirty-two geographical miles from the Pirates' Coast, supposed to be a volcano; Captain Belcher found it about 13,700 feet high, or nearly 4000 feet higher than Gunung Pasaman (Mount Ophir), in Sumatra. (492) But on the other hand, Rajah Brooke mentions a much lower mountain in the Province of Sarawak as bearing the name of Gunung Api (Fire Mountain in Malay), which name and the scoriæ which surround the mountain would indicate a former state of volcanic activity. Great deposits of auriferous sand between quartzose dykes, much tin washed down on both banks of the river, and the felspathic porphyry (493) of the Serambo mountains, indicate a great diffusion of so-called primitive and transition rocks. From the only well-assured determinations which we possess from a well trained geologist, (Dr. Ludwig Horner, son of the meritorious Zurich astronomer and circumnavigator,) washings are carried on at several places in the south-east of Borneo, in which process gold, diamonds, platina, osmium, and iridium are found, as in the Siberian Ural (but hitherto no palladium). A range of hills 3410 feet high, the

Ratuh mountains, is very near, and has formations of serpentine, gabbro, and syenite. ([494])

In the other three great Sunda Isles, Sumatra, Java, and Celebes, Junghuhn counts of active volcanoes;—in Sumatra 6 or 7, in Java 20 or 23, and in Celebes 11; to Flores he assigns 6. We have already spoken in detail, p. 280 to 288, of the volcanoes of Java. In Sumatra, which has not yet been thoroughly explored, out of nineteen conical mountains which have a volcanic appearance, six are active volcanoes. ([495]) Those recognised as such are: Gunung Indrapura, about 11,500 French feet (12,256 English) according to angles of altitude taken at sea (perhaps its height is similar to that of the more exactly measured G. Semeru or Maha-Meru in Java); Gunung Pasaman, also called Ophir, which was ascended by Dr. L. Horner (9602 feet), with an almost extinct crater; Gunung Salasi rich in sulphur; it erupted scoriæ in 1833 and 1845; Gunung Merapi, (9570 feet) also ascended by Dr. L. Horner in company with Dr. Korthal in 1834, the most active of all the volcanoes of Sumatra, and not to be confounded with the two mountains of the same name in Java ([496]); Gunung Ipu, a truncated cone which sends forth smoke; and Gunung Dempo, in the inland district of Bencoolen; its height is estimated at 10,000 French feet (about 10,660 English).

Four small islands, cones of trachyte, of which Peak Rekata and Panahitam (the Prince's islands) are the highest, rise in the Strait of Sunda and connect the Sumatra range of volcanoes with that of Java; and in a similar manner, at the eastern end of Java, its easternmost volcano, Idgien, is connected by the active volcanoes

Gunung Batur and Gunung Ajung on the adjacent island of Bali with the long chain of the Lesser Sunda Isles. We have in succession, proceeding eastward from Bali, in the island of Lombok, the smoking volcano of Rindjani, according to Mr. Melville de Carnbee's trigonometrical measurement 12,363 feet; Temboro (5862 feet), in Sumbawa or Sambawa island, whose eruption of pumice and ashes which darkened the air, in April 1815, is one of the greatest of which history has preserved the record ([497]); and six partly still smoking conical volcanoes in the island of Flores.

The great and many-armed island of Celebes contains six volcanoes which are not yet all extinct. They lie close together in the north-easternmost narrow peninsula of Menado. Sulphurous springs gush forth boiling hot in their vicinity. My Piedmontese friend, Count Carlo Vidua, a very extensive and observant traveller, unhappily fell into one of these springs situated near the route from Sonder to Lamovang, and died from the effects of the inflamed wounds caused by the scalding mud. Like the little island of Banda, one of the Moluccas, which consists of the volcano Gunung Api (only about 1800 feet high, and which was active from 1586 to 1824), the larger island of Ternate also consists solely of the cone of Guning Gama Lama (5755 feet high), whose violent eruptions from 1838 to 1849 are described as having taken place (after an interval of more than a century and a half of entire repose) at ten distinct epochs. Junghuhn tells us that, in the eruption of the 3rd of February 1840, a stream of lava issued from a fissure near Fort Toluko and flowed down to the sea-shore ([498]); he is uncertain "whether the lava may

have formed a connected completely molten mass, or whether it may have issued forth in the form of glowing fragments, which rolled down, and as they followed in close succession pressed each other over the more level ground." If to the more important volcanic cones which have been named above, we add the many very small island-volcanoes which cannot be here enumerated in detail, then the sum total of all the volcanoes situated to the south of the parallel of Cape Serangani, on Mindanao, one of the Philippines, and between the meridians of the north-west cape of New Guinea on the east, and the group of the Nicobar and Andaman islands on the west, amounts, as has been already said, to 109.([499]) It is not, however, meant that these are now all active volcanoes. The estimation has been made in such manner that "in Java it includes 45 volcanoes, most of them being conical and furnished with craters." But of these 45 only 21, and of the whole number of 109 only from 42 to 45 are now active, or are known to have been so within historic times. The great peak of Timor once served, like Stromboli, as a lighthouse to mariners. On the small island Pulu Batu (also called P. Komba), a little to the north of Flores, a volcano was seen in 1850 to pour down glowing lava on the sea-beach, as was also the case with the Peak on the larger Sangir island between Magindanao and Celebes in 1812, and again quite recently in the spring of 1856. Junghuhn doubts whether the conical Mount Wawani or Ateti in Amboina poured forth anything more than hot mud in 1674, and he regards the island as at present belonging only to the class of solfataras. The great group of the South Asiatic islands connects itself on the one hand by

the section of the western Sunda Isles with the Nicobar and Andaman islands of the Indian Ocean, and on the other hand by the section of the Moluccas and Philippines with the Papuas, Pelew islands, and Carolinas of the Pacific. But we will consider next the less numerous and more scattered groups of the Indian Ocean.

7. *The Indian Ocean.*

The Indian Ocean comprises the space between the west coast of the peninsula of Malacca and the east coast of Africa, including therefore the Bay of Bengal and the Arabian and Ethiopian seas. We will follow the direction of the volcanic activity in the Indian Ocean, which is from north-east to south-west.

Barren island, in the Bay of Bengal, a little to the east of the greater Andaman island (12° 15′ N.), is rightly termed an active cone of eruption rising out of a crater of elevation. The sea flows in through a narrow aperture and fills an interior basin. The appearance of this island, which was discovered by Horsburgh in 1791, is exceedingly instructive for the theory of the formation of volcanic frameworks. We see here completed and permanent that which, at Santorin and at other points of the globe, Nature had presented to our observation only transitorily. ([500]) The eruptions in November 1803 were, like those of Sangay in the Cordilleras of Quito, very decidedly periodical, with intervals of ten minutes. (Leop. von Buch, in the Abhandl. der Berlin Akademie, 1818-1819, S. 62).

The island of Narcondam (13° 24′ N.), north of Barren island, has also shown volcanic activity in former

times, as has also the still more northerly conical mountain of the Island of Cheduba (18° 52′ N.), near the coast of Arracan (Silliman's American Journal, vol. 38, p. 385).

The most active volcano, if the abundance of lava poured forth be made the criterion, not only in the Indian Ocean but almost in the whole of that part of the southern hemisphere which lies between the meridians of the west coast of New Holland and the east coast of America, is the volcano of the Island of Bourbon in the group of the Mascareignes. The greater part of the island, in particular the western and inland portion, is basaltic. More recent basaltic dykes, poor in olivine, intersect the older rock which is rich in olivine; and beds of lignite are enclosed in basalt. The culminating points of the mountainous island are Le Gros Morne and Les Trois Salazes whose height was overestimated by Lacaille at 10,000 French feet (10,658 English). The volcanic activity is now confined to the south-eastern part of the island, Le Grand Pays Brulé. The summit of the Volcano of Bourbon, which almost every year sends forth, according to Hubert, two streams of lava, which often reach the sea, is, according to Berth's measurement, 8000 feet high. (501) It shows many cones of eruption to which distinct names have been given, and of which sometimes one and sometimes another sends forth eruptions. The summit itself does so but rarely. The lavas contain glassy felspar, and are therefore trachytic rather than basaltic. The showers of ashes often contain olivine in the form of long and fine threads, a phænomenon which is also found in the Volcano of Owyhee. A great eruption which took

place in 1821 covered the whole Island of Bourbon with these glassy threads.

In the great Terra Incognita of Madagascar, we know only of the wide distribution of pumice at Tintingue, opposite to the French Ile Sainte Marie, and basalt showing itself south of the Bay of Diego Suarez, near the northernmost Cap d'Ambre, surrounded by gneiss and granite. The height of the southern central range of the Ambohistmen mountains is estimated, probably with great uncertainty, at between ten and eleven thousand feet. To the west of Madagascar, at the northern outlet of the Mozambique channel, the largest of the Comoro islands has a burning volcano (Darwin, Coral Reefs, p. 122).

The small volcanic island of St. Paul (in 38° 38′ S.), south of Amsterdam, is called volcanic not only on account of its shape which vividly recalls that of Santorin, Barren island, and Deception island in the New Shetland group, but also on account of the repeatedly observed eruptions of fire and vapour in recent times. The very characteristic drawing given by Valentyn, in his work on the Banda Isles, on the occasion of the expedition of Willem de Vlaming (Nov. 1696), agrees perfectly, as does also the assigned latitude, with the drawings in the Atlas of Lord Macartney's expedition, and with Captain Blackwood's survey in 1842. The crater-shaped circular bay, almost an English mile broad, is every where surrounded (with the exception of one narrow opening through which the sea flows in at high tide) by a high rocky escarpment, having a vertically precipitous face internally, and a gentle and gradual declivity externally. (502)

The Island of Amsterdam (37° 48′ S.), or 50′ of latitude to the north of St. Paul's, consists, according to Valentyn's drawing, of a single, wooded, rather rounded mountain, on the highest part of which rises a small cubical rock almost similar to that on the Cofre de Perote in Mexico. In the expedition of D'Entrecasteaux, in March 1792, the island was seen for two days wrapped in fire and smoke. The smell of the smoke seemed to indicate a forest and earth fire; the voyagers did indeed think they saw columns of smoke rising here and there *out of the ground* near the shore; but the naturalists who accompanied the expedition came to the conclusion that the phænomenon was at least not to be ascribed to the eruption [503] of the high mountain as a volcano. We might adduce as more secure evidences of a more ancient and genuine volcanic activity in the Island of Amsterdam, the beds of pumice (uitgebranden puimsteen) mentioned already by Valentyn, according to Vlaming's ship's journal in 1696.

To the south-east of the extremity of Africa there are Marion's or Prince Edward's island (47° 2′ S.) and Possession island, belonging to the Crozet group (46° 28′ S. lat., and 51° 58′ E. long.). Both show traces of former volcanic activity; they are small conical hills [504] with eruption-orifices surrounded by columnar basalt.

To the eastward, in almost the same latitude, follows Kerguelen island (Cook's Island of Desolation), of which we owe the first geological description to Sir James Ross's antarctic expedition, so fruitful in successful results. At the place called by Cook Christmas Harbour (48° 41′ S. lat., 69° 04′ E. long.), basaltic lavas several feet thick envelope fossil trunks of trees. The

picturesque "Arched Rock" is a natural passage through a narrow projection of basaltic rock. There are in the vicinity conical mounts, of which the highest rise to 2664 feet, with extinct craters; masses of greenstone and porphyry traversed by dykes of basalt, and amygdaloid with quartzose drusic cavities, at Cumberland Bay. Most remarkable are the many beds of coal embedded in trap-rock (dolerite as at Meissner in Hesse?), varying in thickness from a few inches to four feet.([505])

If we cast a general glance over the domain of the Indian Ocean, we see that the extremity of the Sunda range, which in Sumatra has assumed a north-westerly curvature, is prolonged through the Nicobars, the greater and lesser Andamans, and the volcanoes of Barren island, Narcondam and Cheduba, into the eastern part of the Bay of Bengal, in a line almost parallel to the coast of Malacca and Tenasserim. The western part of the Bay of Bengal, along the coasts of Orissa and Coromandel, is without islands; Ceylon, like Madagascar, has rather a continental character. On the western side of the great Indian peninsula, over against the range of the Neilgherries and the coasts of Canara and Malabar, the three groups of the Laccadives, Maldives, and Chagos, form in a north and south direction a chain of islands from 14° N. to 8° S. latitude connecting itself through the banks of Sahia de Malha and Cargados Carajos with the volcanic group of the Mascareignes and with Madagascar; they are all, so far as is visible, structures raised by the coral polypes, true atolls or lagoon reefs; according to Darwin's ingenious conjecture, that we have here a wide space of sea bottom forming an area not of elevation but of subsidence.

8. *The Pacific.*

If we compare the part of the earth's surface which is at present covered by water with the area of dry land (the ratio being approximately ([506]) as 2·7 : 1), we may be struck by surprise in geological respects at the rarity of still active volcanoes in the oceanic region. The Pacific Ocean, whose surface is nearly one sixth greater than that of the whole dry land of our planet,—whose breadth in the equatorial region, from the Galapagos to the Pelew islands, is nearly two fifths of the whole circumference of the globe,— presents fewer smoking volcanoes, fewer openings through which the interior of the planet still maintains an active communication with its atmospheric envelope, than does the single island of Java. The geologist of the great American exploring expedition under the command of Charles Wilkes (1838-1842), the ingenious James Dana, has undoubtedly the great merit of having shed a new light on the whole Pacific world of islands, by taking as a foundation his own researches combined with a careful assemblage and comparison of all well-assured previous observations, and proceeding thence to a generalisation of views repecting the shape, distribution, and direction of axis in all the various groups of islands; the charac- of the rock; and periods of subsidence and elevation of extensive tracts of the bottom of the sea. If I avail myself largely of his writings as well as of the admirable investigations of Charles Darwin, the geologist of Captain Fitz-Roy's expedition in 1832-1836, without special reference on each occasion, the high esteem which I have for so many years expressed for both those

able men will sufficiently obviate the possibility of any misunderstanding.

I prefer to avoid the sectional names arbitrarily and variously given upon grounds respecting either the number and size of islands, or the complexion and descent of their inhabitants, Polynésie, Micronésie, Melanésie, and Malaisie ([507]); and begin the enumeration of still active volcanoes in the Pacific or South Sea with those which are to the north of the equator; and will then proceed to consider, in a direction from east to west, the islands lying between the equator and the parallel of 30° S. The many basaltic and trachytic islets with their countless craters, eruptive formerly but at very different periods, must not indeed be regarded as dispersed without any regularity or definite order. ([508]) We can recognise in the greater number that their elevation has taken place on extended fissures and submarine mountain-ranges, following determinate directions in regions and groups belonging to different systems, as we have seen to be the case in the continental mountain-ranges of Central Asia and the Caucasus; but the relative positions of the very limited number of volcanic apertures which show themselves contemporaneously active at any particular epoch, are probably dependent on very local disturbances affecting the conducting fissures. If we attempt to draw lines through three volcanoes which are all active at the present time and are 2400 and 3000 geographical miles from each other, without any intermediate cases of eruption,—(I mean the volcanoes of Mauna Loa, with Kilauea on its eastern declivity, the conical Mount Tanna in the New Hebrides, and Assumption in the northern Ladrones,)—such lines

could give us no information as to the general genetic connection of the volcanoes in the basin of the Pacific. It is otherwise when we confine our consideration to single groups of islands, and go back in imagination to the, perhaps, pre-historic epochs, when the many now extinct linearly arranged craters of the Ladrones (Marianas), the New Hebrides, and Solomon's islands were in a state of activity; but which craters we are certainly not justified in assuming to have become successively extinct one after another in any particular geographical direction, as, for example, from south-east to north-west, or from north to south. I have here spoken of volcanic ranges of islands in the high seas, but the same reasoning would apply to the Aleutian or other "coast islands." General conclusions respecting the direction of a process of cooling are illusory, on account of the influence on such cooling processes of temporary obstruction or freedom from obstruction in the channels of conduction.

Mauna Loa, or Roa (or Mouna acording to the English mode of writing), which was found by a careful measurement ([509]) of the American exploring expedition under Captain Wilkes to be 13,758 feet high, or 1600 feet higher than the Peak of Teneriffe, is both the greatest volcano in the Pacific, and also is the only one still thoroughly active in the entire volcanic archipelago of the Hawaii or Sandwich islands. The summit-craters, of which the largest is about 13,000 feet in diameter, present in their ordinary state a solid floor of cooled lava and scoriæ from which rise small cones of eruption exhaling vapours. The summit-openings are in general but little active; but in June 1832, and in January 1843,

eruptions took place from them which lasted many weeks, and even sent forth streams of lava from 20 to 28 geographical miles in length, reaching to the foot of Mauna Kea. The angle of inclination of the connected flowing stream ([510]) was for the most part 6°, often from 10° to 15°, and even 25°. A very remarkable feature in Mouna Loa is the absence of any cone of ashes or cinders like the Peak of Teneriffe, Cotopaxi, and so many other volcanoes; pumice is also almost entirely wanting ([511]); although the blackish-grey, rather trachytic than basaltic, lavas of the summit are rich in felspar. The extraordinary fluidity of the lavas of Mouna Loa, whether from the summit-crater (Mokua-weo-weo), or from the lake of lava (situated at a height of only 3969 feet above the sea on the eastern declivity of the volcano), is evidenced by the sometimes smooth and sometimes curled threads of glass which the wind carries and scatters over all the island. This hair-like glass, which is also emitted from the volcano of Bourbon, is called in Hawaii (Owyhee), "Pele's Hair," from the protecting goddess of the country.

Dana, with great sagacity, has shown that Mouna Loa is not a central volcano to the Sandwich island group, and that the lava-lake Kirauea or Kilauea is not a solfatara. ([512]) The longer diameter of the basin of Kilauea is 16,000 feet, and its shorter diameter 7460 feet. The steaming, boiling, heaving fluid of this lava-pool, does not under ordinary circumstances occupy the whole cavity, but only a space a little less than 14,000 feet long and rather more than 5000 feet broad. There is a descent by a kind of steps down the crater margin. This grand phænomenon leaves on the mind a wonderful

impression of stillness and solemn repose. The approach of an eruption is not here announced by earthquakes or subterranean noises, but solely by a sudden rising and falling of the surface of the lava, sometimes from a depth of 300 or 400 feet to the upper margin of the basin, and the reverse. If, disregarding the enormous difference of size, we should be disposed to compare the colossal basin of Kilauea with the small lateral craters (first circumstantially described by Spallanzani) situated on the declivity of Stromboli, at four fifths of its height, and of which the larger are only about 200 and the smaller about 30 feet across, we should remember the important distinction constituted by the fact, that these fiery openings of Stromboli (which is itself unopened at the summit) throw up scoriæ to a great height, and even pour forth lavas. Although the great lava-lake of Kilauea (which may be termed the lower and secondary crater of the active volcano of Mouna Loa) may sometimes threaten to overflow its margin, yet it never has actually so overflowed as to give birth to a proper stream of lava. Such streams are, however, formed by the descent of the lava through subterranean channels, and by the formation of new openings of eruption at a distance of 16 or 20 miles from the fiery lake at points much lower down. After such eruptions, occasioned by the pressure of the enormous mass of lava in Kilauea, have taken place, the surface of the lava in the basin sinks to a lower level. ([513])

Of the other two high mountains in Hawaii, Mouna Kea and Mouna Hualalai, the first is, according to Captain Wilkes, 192 feet higher than Mouna Loa: it is a mountain cone whose summit no longer presents

a terminal crater, but only hills of long extinguished scoriæ. Mouna Hualalai* is about 10,000 feet high, and is still burning. In 1801 an eruption took place in which the lava reached the sea on the western side. It is to the elevation from the bottom of the sea of the three great mountains of Loa, Kea, and Hualalai, that the whole of the island of Hawaii owes its origin. In the descriptions of the many ascents of Mouna Loa, among which that given by Captain Wilkes' Expedition rests on examinations continued during 28 days, a fall of snow with a temperature of from 9° to 14° below the freezing point is spoken of, and single patches of snow near the summit are said to have been seen from a distance by the aid of a telescope; but perpetual snow is never mentioned. ([514]) I have already remarked that according to the measurements which we may now regard as most accurate, 13,759 feet for Mouna Loa, and 13,951 feet for Mouna Kea, those mountains are fully 1000 and 800 feet below what I found to be the lower limits of perpetual snow on the continental mountains of Mexico in 19½° of latitude. We should expect to find the limit of *perpetual* snow rather lower down on a small island than on a continent, on account of the influence of the surrounding ocean in occasioning, in the hot season, a lower temperature of the inferior atmospheric strata, and the presence of a greater quantity of aqueous vapour in the higher portions of the atmosphere over the island.

The volcanoes of Tafoa* and Amargura*, in the Tonga group, are both active, and the latter sent forth a considerable flow of lava on the 9th of July 1847. ([515]) It is an exceedingly remarkable circumstance, and in

complete accordance with the experience that the coral animals avoid the coasts of volcanoes which now are or have recently been in a state of activity, that the Tonga islands (rich in coral-reefs) of Tafoa and of the cone of Kao are quite stripped of living coral. ([516])

The volcanoes of Tanna * and Ambrym * come next; the latter is to the west of Mallicollo, in the group of the New Hebrides. The volcano of Tanna, which was first described by Reinhold Forster, was found in full eruption on Cook's first discovery of the island in 1774. It has continued active ever since, and as its height is scarcely 460 feet, it must be ranked, together with the Japanese Kosima and the volcano of Mendaña mentioned below, as belonging to the class of the least elevated of fire-emitting mountains. On Mallicollo is much pumice.

Mathews Rock * is a small island-rock about 1180 feet high, which sends forth smoke, and which D'Urville observed in eruption in January 1828. It is to the east of the south point of New Caledonia.

The volcano of Tinakoro *, in the Vanikoro or Santa Cruz group.

In the same archipelago of Santa Cruz, fully 80 geographical miles N.N.W. of Tinakoro, there rises from the sea a small volcano * only about 200 feet in height (under 200 French or 213 English feet), which was first seen by Mendaña in 1595. It is in 10° 23′ S. Its fiery eruptions have sometimes been periodical, occurring every ten minutes; and sometimes, as when seen by D'Entrecasteaux's expedition, the column of vapour may be said to have been itself the crater.

In the Solomon group there is an active volcano on

the island Sesarga.* Near to t, and therefore near also to the south-eastern extremity of the long range of islands, and in the direction of the Vanikoro or Santa Cruz group, outbreaks of volcanic activity have been remarked on the coast of Guadalcañar.

In the Ladrones, or Marianas, in the northern part of that range of islands which seems to have been elevated from a fissure running in the direction of the meridian, Guguan *, Pagon *, and the Volcan Grande of Asuncion * are said to be still active.

The direction of the coast-line of the small continent of New Holland, and especially the alteration of direction undergone by its east coast in 25° S. (between Cape Hervey and Moreton Bay) appears reflected, or repeated, in the zone of neighbouring eastern islands. The great southern island of the two islands of New Zealand, and the Kermadec and Tonga groups have a general south-west and north-east direction: while on the other hand the northern part of the northern island of New Zealand, from the Bay of Plenty to Cape Oton, New Caledonia and New Guinea, the New Hebrides, the Solomon Islands, New Ireland and New Britain, all follow a south-east and north-west direction, for the most part N. 48° W. Leopold von Buch ([517]) was the first to call attention to these relations between continental masses and the neighbouring islands, in the case of the archipelago of Greece, and of the coral-sea of Australia. In the islands of this last-named sea also, as was already remarked both by Cook's companion, Forster, and La Billardière, granite and mica-slate, the quartzose rocks which were once termed primitive, are not wanting. Dana has also found them in the northern island of

New Zealand, to the west of Tipuna, in the Bay of Islands. ([518])

At the southern extremity of New Holland (Australia Felix), at the foot and to the south of the Grampians, fresh traces of ancient volcanic action are found: and to the north-west of Port Phillip there are, according to Dana, a umber of volcanic cones and lava beds, as also towards the Murray River (Dana, p. 453).

In New Britain *, near its eastern and its western coasts, at least three cones have been observed as burning and yielding lavas within historic times, by Tasman, Dampier, Carteret, and La Billardière.

There are two active volcanoes on the north-east coast of New Guinea, opposite to New Britain and the Admiralty islands, which are rich in obsidian.

In New Zealand, where the geology of the northern island at least has been well elucidated by the important work of Ernst Dieffenbach and the fine investigations of Dana, basaltic and trachytic rock breaks through the generally diffused plutonic and sedimentary rocks at several points; for instance, in an exceedingly small area near the Bay of Islands in 35° 2′ S., where rise the cones of ashes, crowned by extinct craters, of Turoto and Poerua; so also, further to the south (between 37½° and 39¼° S.), a strip of volcanic ground extends across the whole of the northern island, a distance of more than 160 miles from north-east to south-west, from the eastern Bay of Plenty to the western Cape Egmont. Here, as we have seen on a larger scale on the American continent (in Mexico), this zone of volcanic activity appears as a cross fissure running from sea to sea, and intersecting at a considerable angle the long inland

chain of mountains which seems to give the form to the entire island. On the volcanic cross fissure, and as it may seem at the point of intersection, we have the high cone of Tongariro* (6198 feet), whose crater on the cone of ashes has been reached by Bidwell; and, rather more to the south, Ruapahu (9005 feet). The north-east extremity of the zone is formed by a constantly smoking solfatara, the island-volcano of Puhia-i-wakati* ([519]) (White island, in the Bay of Plenty, lat. 38½° S.). Returning to the south-west, we have first, on the coast itself, the extinct volcano of Putawaki (Mount Edgecombe), 9630 feet high; a snow-clad mountain, and probably the loftiest in New Zealand; and inland, between Mount Edgecombe and the still burning Tongariro*, which has poured forth some streams of lava, we find a long chain of lakes of which some are of boiling water. The lake of Taupo, which is surrounded by fine shining leucite and sanidine sand, and by hills of pumice, is nearly twenty-four miles in length; it is in the middle of the northern island of New Zealand, and is 1337 feet above the level of the sea, according to Dieffenbach. The space around, for two English square miles, is covered with solfataras, caves emitting vapours, and thermal springs; which last, like the geysirs in Iceland, form a variety of deposits of silicates. ([520]) To the west of Tongariro*, the principal seat of volcanic activity, whose crater still emits vapours and pumice ashes, and which is only sixteen geographical miles distant from the western sea, rises the volcano of Taranaki (Mount Egmont), 8838 feet high and which was first ascended and measured by Dr. Ernst Dieffenbach in November 1840. The summit of the cone, of which

the outline resembles that of Tolima more than that of Cotopaxi, terminates in a plateau from which there rises a very steep cone of ashes. No traces of present activity, as on the volcano of White Island* and that of Tongariro*, have been observed; nor any connected lava-streams. Masses of a ringing kind of rock laminated in very thin scales, and which project, as on one side of the Peak of Teneriffe, in sharp ridges from among scoriæ of the cone of ashes itself, resemble porphyritic schist (or phonolite).

A narrow, long-extended, uninterrupted series of island groups over south-east and north-west fissures, as New Caledonia and New Guinea, the New Hebrides and Solomon Islands, Pitcairn, Tahiti, and the Paumotu islands, cross the great Pacific Ocean in the southern hemisphere between the parallels of 12° and 27° S., extending in an east and west direction over 5400 geographical miles, from the meridian of the east coast of Australia to Easter Island and the Rock Sala y Gomez. The western portions of this great congeries of islands (New Britain*, the New Hebrides*, Vanikoro* in the Santa Cruz archipelago, and the Tonga* group) show at the present time (the middle of the 19th century) igneous activity. New Caledonia, although surrounded by basaltic and other volcanic islands, has merely plutonic rocks ([521]), as is the case in the Azores with Santa Maria ([522]) according to Leopold von Buch, and also with Flores and Graciosa according to Count Bedemar. To this absence of volcanic activity in New Caledonia, where sedimentary formations and beds of coal have lately been discovered, is ascribed the great development of live coral-reefs. The group of the Viti or Feejee

islands is both basaltic and trachytic, yet in the point of view now under consideration it is only distinguished by hot-springs in Savu Bay in the island of Vanua Leboo.([523]) The Samoa group (Navigator's islands), north-east of the Feejee, and almost due north of the still volcanically active Tonga group, is also basaltic, and is characterised by a great number of linearly arranged craters of eruption surrounded by beds of tufa with inbaked pieces of coral. Most remarkable, geologically, is the Peak of Tafua in the island of Upolu belonging to the Samoa group, and not to be confounded with the still burning Peak of Tafoa south of Amargura in the Tonga group. The Peak of Tafua, 2138 feet high, which was first ascended and measured by Dana ([524]), has a large crater quite filled with forest trees and crowned by a regularly rounded cone of ashes. There are no traces of lava-streams, but there are scoriaceous lava-fields (Malpais of the Spaniards), with curled and often reticulated surface of the lava, at the conical Mountain of Apia (2576 feet), also in the island of Upolu, as well as at the Peak of Fao which reaches a height of 3000 French (3197 Eng.) feet. The lava-fields of Apia contain narrow subterrannean caves.

Tahiti in the middle of the Society islands is much more trachytic than basaltic; it shows, properly speaking, only the ruins of its former volcanic framework; and amidst these grand remains, forming sometimes lofty walls and sometimes jagged peaks, with vertical precipices several thousand feet in depth, it is difficult to decipher the original form of the volcano. Of the two highest summits, Aorai and Orohena, Aorai was ascended first by Dana ([525]), and examined by that sound geolo-

gist. The trachytic mountain Orohena is said to be as high as Etna. Tahiti has, therefore, next to the active group of the Sandwich islands, the loftiest eruptive rock in the whole of the great oceanic domain lying between the continents of America and Asia. A felspathic rock of the small islands of Borabora and Maurua in the vicinity of Tahiti, which later travellers have termed syenite, and which Ellis in his "Polynesian Researches" designates as a granitic aggregate of felspar and quartz, is deserving of a much more exact mineralogical examination; as porous scoriaceous basalt breaks forth in near proximity to it. Neither extinct craters nor streams of lava are now found in the Society islands. It is natural to ask, have the craters on the mountain-summits been destroyed? or are the now riven and altered remains of the volcanic frameworks the ruins of closed domes? or may we suppose that here, as has probably been the case at many other points of the upheaved sea bottom, basalt and trachyte beds have been poured forth directly from earth-fissures? Extremes of great tenacity or of great fluidity in the substances which issued forth, as well as differences of narrowness or breadth in the fissures through which they have issued, modify the shape assumed by the volcanic rocks formed by them; and where friction produces trituration into small fragments and into what are then called ashes, small, and most often transitory, cones of eruption arise, which are not to be confounded with the great terminal cones of ashes of permanent frameworks.

At only a short distance to the east of the Society islands there follow the Low islands, or Paumotu. These are mere coral-islands, with the remarkable ex-

ception of the small basaltic group of Gambier and Pitcairn islands. ([526]) Volcanic rock, as in these last, is also found in the same parallel (between 25° and 27° S.) 1260 geographical miles more to the eastward in Easter Island (Waihu), and probably also 240 miles further, in the Sala y Gomez rock. On Waihu, where the highest conical summit is only about 1000 feet high, Captain Beechey observed a range of craters, none of which, however, appeared to be burning.

The islands of the Pacific at their extreme eastern termination on the side of the American continent conclude with the group of the Galapagos; one of those in which volcanic activity is most developed. Scarcely anywhere in so small a space, barely 120 or 140 geographical miles in diameter, have so many conical mountains and extinct craters (traces of ancient communication between the interior and the atmosphere) remained visible. Darwin estimates the number of craters at almost 2000. When he visited these islands in the expedition of the Beagle under Captain Fitz-Roy, two craters were simultaneously in fiery eruption. In all the islands, streams of very fluid lava may be seen separating into branches, and often reaching the sea. Almost all are rich in augite and olivine, and some which are more trachytic are said to contain albite ([527]) in large crystals. It would be well in the present state of improved mineralogical knowledge to examine whether these porphyritic trachytes do not contain oligoclase, as at Teneriffe and in Popocatepetl and Chimborazo; or labradorite, as in Etna and Stromboli. Pumice is entirely wanting in the Galapagos, as in Vesuvius, as a production of the volcano itself; neither is hornblende ever mentioned as

having been found in them, so that we have not here the trachyte formation of Toluca, Orizaba, and of some of the volcanoes of Java, from which Dr. Junghuhn sent me selected solid pieces of lava to be examined by Gustav Rose. In Albemarle island, which is the largest and westernmost of the Galapagos, the conical mounts are arranged linearly, and we may infer therefore over fissures. Their greatest height, however, does not exceed 4636 feet. The western bay, in which rises the island peak of Narborough which in 1825 was in vehement eruption, is described by Leopold von Buch ([528]) as a crater of elevation, and is compared to Santorin. Many of the margins of craters in the Galapagos are formed of beds of tufa which fall away on all sides. It is remarkable, and indicative of the simultaneous action of a great catastrophe, that all the crater-margins are either broken down or entirely destroyed on their southern side. Part of what in older descriptions is termed tufa consists of beds of palagonite, quite similar to that of Iceland and Italy, as has been established by Bunsen's exact analysis of the tufas of Chatham island. ([529]) This, which is the easternmost island of the entire group, and of which the exact position has been astronomically determined by Beechey, is still 536 geographical miles distant from Punta de S. Francisco on the American continent, according to my determination of the longitude of the town of Quito, 81° 4′ 38″ W. from Paris, and Acosta's Mapa de la Nueva Granada of 1849.

9. *Mexico.*

The six Mexican volcanoes, Turtla*, Orizaba, Popocatepetl*, Toluca, Jorullo*, and Colima*, four of which have been burning within historic times, have already been enumerated ([530]), and their geologically remarkable relative positions described. According to recent examination by Gustav Rose the formation of the rock of Popocatepetl, the great volcano of Mexico, is the same as that of Chimborazo, consisting, like it, of oligoclase and augite. Even in the almost black beds of trachyte, resembling pitchstone, oligoclase can be recognised in very small crystals with oblique angles. The volcano of Colima on the western side, on the shore of the Pacific, belongs to the same Chimborazo and Teneriffe formation. I have not myself seen Colima; but we owe to Pieschel ([531]) (since the spring of 1855) a very instructive review of the rocks collected by him, as well as interesting geological notices upon the volcanoes of the entire Mexican highland, all of which he has himself visited. The volcano of Toluca, whose narrow highest summit of difficult access (the Pico del Frayle), was ascended by me on the 29th of September, 1803, and its height determined barometrically at 15,168 feet, is very different in mineralogical composition from the still active Popocatepetl, and the volcano of Colima, which is not to be confounded with another higher, snow-clad summit of the same name. The volcano of Toluca consists, like the Peak of Orizaba, Puy de Chaumont in Auvergne, and Ægina, of an association of oligoclase and hornblende. According to the above short statement we perceive that, in the long series of volcanoes extending

from sea to sea, no two successive members have the same mineralogical composition, a circumstance very deserving of attention.

North-western America

(North of the parallel of the Rio Gila).

In the section which treated of the volcanic activity of the East-Asiatic islands ([532]), particular importance was attached to the bow-shaped curvature of the fissure of elevation from which the Aleutian islands have risen, and which manifests an immediate connection between the Asiatic and American continents, *i. e.* between the two volcanic peninsulas Kamtschatka and Aliaska (Alashka). We may call this the northern boundary of a great bay of the Pacific Ocean, which, from a breadth of 150° of longitude which it occupies at the equator, diminishes to 37° of longitude between the points of the two above-named peninsulas. On the American continent, near the sea, a number of more or less active volcanoes have been known to mariners for the last seventy or eighty years; but this group has been hitherto regarded as isolated, unconnected either with the volcanic series of tropical Mexico, or with the volcanoes supposed to exist in the peninsula of California. Now, when a series of extinct trachytic cones are regarded as intermediate links, an insight into their important geological connection has been gained by the filling up of what was previously a gap, extending over more than 28° of latitude, between Durango and the new Washington territory north of West Oregon. This important step in physical geography is due to the expedition sent

by the United States government to seek for the best route from the plains of the Mississippi to the shores of the Pacific; the expedition was also well prepared in scientific respects, and all parts of natural history have benefited by it. In the now explored *terra incognita* of this interval, great strips of country, very near to the Rocky Mountains on their eastern side, and extending to a considerable distance from their western declivities, have been found covered by the products of either extinct or still active volcanoes. We may thus see that, beginning from New Zealand, and proceeding first for a considerable distance in a north-west direction we can pass through New Guinea, the Sunda islands, the Philippines, and the east of Asia, and ascending to the Aleutian islands, can redescend to the southward through the north-western part of America, Mexico, Central and South America, to the extremity of Chili; thus making the entire circuit of the Pacific Ocean, and finding it surrounded, throughout a length of 26,400 geographical miles, by a series of recognisable monuments of volcanic activity. Such a general cosmical view could not have been gained, and based on adequate grounds, without entering into particulars of exact geographical direction and improved classification.

Of the circumference of the great sea-basin here spoken of, (or, inasmuch as there is but one throughout-communicating body of oceanic waters upon the earth, we ought rather to say ([533]), of the circumference of the largest of those portions of the ocean which form as it were bays or gulfs between continents,) there still remain to be described the regions which extend from the Rio Gila to Norton's and Kotzebue's Sounds. Analo-

gies derived from Europe, from the chains of the Pyrenees or the Alps, and from South America from the Cordilleras of the Andes from the south of Chili to the fifth degree of north latitude in New Granada, supported by fanciful representations in maps, have propagated the erroneous opinion that the Mexican high mountains, or at least their highest ridge, can be traced, as a wall-like rampart, from south-east to north-west under the name of a "Sierra Madre." In reality, however, the mountainous part of Mexico is a broad mighty intumescence, which does indeed hold its way continuously at a height of from 5300 to 7400 feet, in the assigned direction, between the two seas; but upon which, as in the Caucasus and in Central Asia, loftier volcanic mountain-systems following partial and very different directions rise to above 15,000 and 17,800 feet. The directions of these partial groups, which have broken forth over fissures which are also not parallel with each other, are for the most part independent of the ideal axis which can be drawn through the middle of the whole swelling wave of the flattened ridge. These remarkable relations in the form of the ground, occasion an illusion which heightens the picturesque effect of this beautiful land. The giant mountains clothed with perpetual snow appear to rise as from a plain. The surface of the softly swelling undulation, or the "high plain," is scarcely distinguished from the plains of the lowlands; and it is only the climate, the diminished temperature under the same parallel of latitude, which reminds us that we have ascended. The often-mentioned elevation-fissure of the volcanoes of Anahuac (running east and west between the parallels of 19°

and $19\frac{1}{4}°$ N. lat.) cuts the axis of the general undulation almost at right angles. ([534])

The form of a considerable part of the earth's surface here indicated, and which was only begun to be made out by careful measurement since 1803, is not to be confounded with swellings of the surface which are found included between two wall-like bounding mountain chains, as in Bolivia around the lake of Titicaca, and in Central Asia between the Himalaya and the Kuen-lun. The first of these two last-named swellings, the South American, which at the same time forms as it were the floor of the valley, has, according to Pentland, a mean elevation of about 12,850 feet above the sea; and the Thibetian, according to Captain Henry Strachey, Joseph Hooker, and Thomas Thomson, an elevation of about 15,000 feet. The wish expressed by me half a century ago, in my very detailed Analyse de l'Atlas geógraphique et physique du royaume de la Nouvelle Espagne (§ xiv.), that my profile of the high plain between the city of Mexico and Guanaxuato might be continued by measurements over Durango and Chihuahua to Santa Fé del Nuevo Mexico, has now been completely fulfilled. The distance, allowing only one fourth for the inflections, is much more than 1200 geographical miles; and the peculiar characteristics of this long unregarded feature of the earth's surface (the gentle slope and great breadth of the undulation, *i. e.* from 240 to 280 geographical miles) are evidenced by the circumstance that the distance between Santa Fé and Mexico, (a difference of latitude of fully 16° 20′, and a distance about equal to that between Stockholm and Florence,) can be travelled, on the table land, in

four-wheeled carriages, without artificial roads. The possibility of such communication was already known to the Spaniards at the end of the sixteenth century, when the viceroy, the Conde de Monterey ([535]), planned the first settlement of Zacatecas.

In confirmation of what has been said above in general of the relations of altitude between the city of Mexico and the town of Santa Fé del Nuevo Mexico, I subjoin the principal elements of the barometric levellings taken from 1803 to 1847. I have given the places in the order from north to south, so that the more northerly being highest in the page may correspond most conveniently to the arrangement in ordinary maps. ([536]) (The initials indicate the observer, W. signifies Wislizenus; B., Burkart; H., Humboldt.)

Santa Fé del Nuevo Mexico (lat. 35° 41′ N.). Elevation 7046 feet, W.

Albuquerque ([537]) (35° 08′ N.). Elevation 4849 feet, W.

Paso del Norte ([538]) on the Rio Grande del Norte (29° 48′ N.). Elevation 3791 feet, W.

Chihuahua (28° 32′ N.), 4638 feet, W.

Cosiquiriachi 6273, feet, W.

Mapimi in the Bolson de Mapimi (25° 54′ N.), 4782 feet, W.

Parras (25° 32′ N.), 4985 feet, W.

Saltillo (25° 10′ N.), 5240 feet, W.

Durango (24° 25′ N.), 6848 feet, Oteiza.

Fresnillo (23° 10′ N.), 7244 feet, B.

Zacatecas (22° 50′ N.), 9012 feet, B.

San Luis Potosi (22° 08′ N.), 6090 feet, B.

Aguas calientes (21° 53′ N.), 6262 feet, B.
Lagos (21° 20′ N.), 6377 feet, B.
Villa de Leon (21° 07′ N.), 6134 feet, B.
Silao, 5911 feet, B.
Guanaxuato (21° 0′ 15″ N.), 6836 feet, H.
Salamanca (20° 40′ N.), 5762 feet, H.
Celaya (20° 38′ N.), 6017 feet, H.
Queretaro (20° 36′ 39″ N.), 6363 feet, H.
San Juan del Rio in the State of Queretaro (20° 30′ N.), 6491 feet, H.
Tula (19° 57′ N.), 6734 feet, H.
Pachuca, 8140 feet, H.
Moran, near Real del Monte, 8511 feet, H.
Huehuetoca, at the northern end of the great plain of the city of Mexico (19° 48′ N.), 7533 feet, H.
Mexico (19° 25′ 45″ N.), 7469 feet, H.
Toluca (19° 16′ N.), 8824 feet, H.
Venta de Chalco, south-eastern end of the plain of the city of Mexico (19° 16′ N.), 7712 feet, H.
San Francisco Ocotlan, western end of the great plain of Puebla, 7680 feet, H.
Cholula, at the foot of the ancient terraced pyramid (19° 02′ N.), 6906 feet, H.
La Puebla de los Angeles (19° 0′ 15″ N.), 7200 feet, H.
The village of Las Vigas marks the eastern end of the high plain of Anahuac, 19° 37′ N.; the elevation of the village is 7814 feet, H.

Whereas before the commencement of the nineteenth century not a single barometric measurement of altitude had been made in New Spain, it has now become possible to assign, as above, a chain of thirty-two stations

throughout a zone of more than 16° of latitude, from Santa Fé to the city of Mexico, all hypsometrically determined, and the greater part having also their geographical positions fixed astronomically. In looking over this zone we see the surface of the high broad Mexican plain undulate between 5500 and 7000 French feet (5862 and 7460 English). The lowest portion of the route from Parras to Albuquerque is still more than a thousand feet higher than the highest part of Vesuvius.

This great but gentle swelling ([539]), the highest part of which we have now been considering, increases so much in breadth from its tropical portion to the parallels of 42° and 44°, that the breadth of the "Great Basin," west of the Mormons' Salt Lake, is upwards of 340 geographical miles, with a mean elevation of 4260 feet. It is everywhere very distinct from the rampart-like chains of mountains which surmount it. The knowledge of this form is one of the principal fruits of Fremont's great hypsometrical investigations in 1842 and 1844. The swelling belongs to a different and earlier epoch than the comparatively late elevation of the mountain-ranges and systems of varying direction. At the point where, about the 32d parallel of latitude according to the present boundary-determinations, the mountains of Chihuahua enter the western territory of the United States, (the provinces which have been separated from Mexico,) the mountains have already assumed the somewhat indefinite name of Sierra Madre. It is not, however, until near Albuquerque that a decided bifurcation ([540]) takes place. At this bifurcation the western branch retains the general name of Sierra Madre, and

the eastern one, from 36° 10′ lat. northwards (a little to the north-east of Santa Fé), has received from American and English travellers the now everywhere recognised, though not happily selected, name of the Rocky Mountains. The two chains form between them a longitudinal valley in which Albuquerque, Santa Fé, and Taos are situated, and through which the Rio Grande del Norte flows. In 38½° N. lat. the valley is closed by a chain running east and west for nearly 90 geographical miles. The Rocky Mountains are continued in an undivided north and south line to 41° N. In this interval rise, rather on the eastern side, the Spanish peaks; Pike's Peak (5798 feet), of which Fremont has given a fine view; James's Peak (11,433 feet); and the three Park Mountains, which enclose three high caldron-shaped valleys whose lateral walls rise in the eastern Long's Peak, or Big Horn, to heights of 9060 and 11,190 feet. (541) At the eastern edge, the boundary between Middle and North Park, the chain of mountains alters its direction, and from 40¼° to 44° N., for a distance of about 260 geographical miles, runs from south-east to north-west. It is in this portion that the South Pass, 7490 feet, occurs, as well as the wonderfully pointed and serrated Wind-River Mountains, with Fremont's Peak (43° 08′) which rises to the height of 13,567 feet. In the parallel of 44° N., near the Three Tétons, the north-western direction ceases and the north and south direction of the Rocky Mountains is resumed. It is maintained as far as Lewis and Clarke's Pass in 47° 02′ N., 112° W. There the chain of the Rocky Mountains has still a considerable height (5977 feet), but on account of the many deep river beds towards Flathead

River (Clarke's Fork), it becomes more regular and simple. Clarke's Fork and Lewis (or Snake) River form the great Columbia River, which will one day be an important commercial route. (Explorations for a railroad from the Mississippi River to the Pacific Ocean made in 1853-1854, vol. i. p. 107.)

As is the case in Bolivia, where the eastern chain of the Andes, in which are the mountains of Sorata (21,288 feet) and Illimani (21,148 feet), does not now present any still active volcanoes, so also in these western parts of the United States volcanic activity is at present limited to the coast chain of California and Oregon. The long chain of the Rocky Mountains, of which the distance from the sea coast of the Pacific varies from 480 to 800 geographical miles, and having no traces of still-subsisting volcanic activity presents, however, like the eastern chain of Bolivia in the valley of Yucay ([542]), on both its declivities volcanic rocks, extinguished craters, and even lavas with included obsidian and fields of scoriæ. In this part of the Rocky Mountains, which has been described from the excellent examinations of Fremont, Emory, Abbot, Wislizenus, Dana, and Jules Marcou, the last-named distinguished geologist enumerates three groups of ancient volcanic rocks on the two declivities. The earliest proofs of the volcanicity of this district were also due to Fremont's observational habits, commencing in 1842 and 1843. (Report of the Exploring Expedition to the Rocky Mountains in 1842, and to Oregon and North California in 1843—1844, pp. 164, 184—187, and 193.)

On the eastern slope of the Rocky Mountains, on the south-western route from Bent's Fort on the Arkansas

River to Santa Fé del Nuevo Mexico, there are two extinct volcanoes, the Raton Mountains ([543]), with Fisher's Peak, and (between Galisteo and Peña Blanca) the hill of El Cerrito. The lavas of the first of these cover over the whole country between the Upper Arkansas and the Canadian River. The peperino and volcanic scoriæ, which begin already to be found in the prairies in approaching the Rocky Mountains from the eastward, may perhaps belong to ancient eruptions of the Cerrito, or possibly even of the great Spanish peaks (37° 32′ N.). This eastern volcanic domain of the isolated Raton Mountains forms an area of 80 geographical miles in diameter; its centre is somewhere about 36° 50′ N.

On the western slope of the Rocky Mountains, the most clearly marked evidences of ancient volcanic activity occupy a much wider space, which has been traversed throughout its breadth from east to west by the important expedition of Lieutenant Whipple. This area, which is exceedingly irregular in outline, and is moreover interrupted for a length of fully 120 geographical miles by the Sierra de Mogoyon, is comprised (always speaking according to Marcou's geological map) between the parallels of 33° 48′ and 35° 40′. These outbursts have therefore been more to the south than those of the Raton Mountains: their mean latitude is nearly that of Albuquerque. The area thus spoken of divides itself into two sections; that of the part of the crest of the Rocky Mountains near Mount Taylor, which terminates in the Sierra de Zuñi ([544]), and the more western division, called Sierra de San Francisco. The conical Mount Taylor, 12,256 feet high, is surrounded by radiating lava-streams, which can be dis-

tinctly traced as "malpais," still devoid of vegetation, and covered with scoriæ and pumice, following a winding course for distances of many miles, in the same manner as around Hecla. About 70 geographical miles to the west of the present Pueblo de Zuñi rises the lofty volcanic mountain ridge of San Francisco itself, whose summit is estimated at full 16,000 feet; it runs to the south of the Rio Colorado Chiquito, and further to the west follow Bill William Mountain, the Aztec Pass (6279 feet), and the Aquarius Mountains (8526 feet). The volcanic rock does not terminate at the confluence of the Bill William Fork with the Great Colorado River, near the village of the Mohave Indians (in $34\frac{1}{4}°$ N. 114° W.); for several extinct, but still open, craters of eruption can be recognised beyond the Rio Colorado, near the Soda Lake. ([545]) Thus we see here, in the present New Mexico, in the volcanic group of the Sierra de San Francisco, to a little to the westward of the Rio Colorado Grande or del Occidente (into which the Gila falls), throughout an extent of 180 geographical miles, a repetition of the ancient volcanic domain of Auvergne and the Vivarais, and the opening of a new and wide field to geological research.

Also on the western side, but 540 geographical miles more to the north, we find the third ancient volcanic group of the Rocky Mountains, that of Fremont's Peak and of the two "Three Mountains," which are very much like the Trois Tétons and the Three Buttes ([546]), both in conical form and in name: they are to the west of these, and therefore further from the chain. They present wide-spread and much rent and torn black banks of lava, with a scoriaceous surface. ([547])

Several littoral or coast chains run parallel to the chain of the Rocky Mountains, sometimes in single, sometimes in double ranges; and in their northern portions (from 46° 12′ N.) are still the seat of volcanic activity. We have first, from San Diego to Monterey (from $32\frac{1}{4}$° to $36\frac{3}{4}$° N.), the "Coast Range," specially so called, a continuation of the ridge of land of the peninsula of Old or Lower California; then, generally at a distance of about 80 geographical miles from the shore of the Pacific, the Sierra Nevada (de Alta California), from 36° to $40\frac{3}{4}$°;—then, beginning from the high Shasty Mountains in the parallel of Trinidad Bay (41° 10′), the Cascade Range, which includes the highest summits still burning, and extends from south to north, at a distance of 104 miles from the coast, to far beyond the parallel of the Fuca Strait. Running in the same direction, from 43° to 46° N., but at a distance of 280 miles from the coast, the Blue Mountains rise to a mean height of 8000 feet. (548) In the middle portion of Old California, but a little to the north, near the eastern coast (the western shore of the gulf), in the district of the former mission de San Ignacio, in about 28° N., we find the extinct volcano, called the "Volcanes de las Virgenes," which I have set down in my map of Mexico. This volcano had its latest eruption in 1746: we require more certain information respecting both it and the whole surrounding district. (See Venegas, Noticia de la California, 1757, t. i. p. 27; and Duflot de Mofras, Exploration de l'Orégon et de la Californie, 1844, t. i. pp. 218 and 239.)

Rocks belonging to ancient volcanoes have been already found in the Coast Range near the port of San Francisco,

at the Monte del Diablo (3672 feet), which has been examined by Dr. Trask, in the gold-yielding longitudinal valley of the Rio del Sacramento, and in a fallen-in trachytic crater called the Sacramento Butt, which has been drawn by Dana. Further to the north, the Shasty or Tshashtl Mountains, contain basaltic lavas; obsidian, used by the natives for arrow-points; and the talcose serpentines, which at many points of the earth's surface occur in near connection with volcanic formations. But the proper seat of still-subsisting volcanic activity is found in the Cascade Mountains, where several peaks, covered with perpetual snow, rise to heights of 15,000 and 16,000 feet. I subjoin a list of such mountains, proceeding from south to north, and, as before, marking by an asterisk those which are still more or less active volcanoes. The lofty conical mountains not so marked are probably in part extinct volcanoes, and in part unopened trachytic summits.

Mount Pitt or M'Laughlin, in 42° 30′, rather to the west of Lake Tlamat, height 9549 feet.

Mount Jefferson or Vancouver, in 44° 35′; a conical mountain.

Mount Hood, in 45° 10′; certainly an extinct volcano, covered with cellular lava: according to Dana, it and Mount St. Helen's are between 15,000 and 16,000 feet high, Mount St. Helen's being a little the highest. (549) Mount Hood was ascended in August 1853, by Lake, Travaillot, and Heller.

Mount Swalalahos, or Saddle Hill, S.S.E. of Astoria (550), with a fallen-in extinct crater.

Mount St. Helen's *, north of the Columbia River, in

46° 12′ N., at least upwards of 15,000 feet high, according to Dana (551); still burning, always sending forth smoke from the summit-crater: a volcano covered with perpetual snow, of very fine and regular conical form: on the 23d of November, 1842, a great eruption took place, which, according to Fremont, has covered the country all around for a great distance with ashes and pumice.

Mount Adams, in 46° 18′ N., almost due east of Mount St. Helen's; more than 112 geographical miles from the coast: the last-named still-burning mountain being only 76 miles therefrom.

Mount Reignier *, also written Mount Rainier, in 46° 48′ N.; E.S.E. from Fort Nisqually on Puget's Sound, which is connected with the Fuca Strait; a burning volcano: according to Edwin Johnson's map in 1854, 12,330 feet high: it had violent eruptions in 1841 and 1843

Mount Olympus, in 47° 50′ N., only twenty-four geographical miles south of the strait of San Juan de Fuca, so long celebrated in the History of Discovery in the Pacific.

Mount Baker*; a great and still active volcano in the territory of Washington (in 48° 48′), rising to a great height (? not yet measured), and of very regular conical form.

Mount Brown (16,000 feet?), and a little to the east of it Mount Hooker (16,730 feet?), are, according to Johnson, lofty mountains of ancient volcanic trachyte in New Caledonia, in $52\frac{1}{4}$° N. and 118° and 120° W., remarkable therefore for being more than 300 geographical miles from the coast.

Mount Edgecombe*, on the small island called Lazarus island, near Sitka, in 57° 3′ N., whose violent fiery eruption in 1796 I have already spoken of in the present volume (English translation, Note 387). Captain Lisiansky, who ascended it in the early part of the present century, found the volcano not then burning. Its height (552) according to Ernst Hofmann is 3040 feet, according to Lisiansky 2801 feet: there are hot springs near it which break forth from granite like those which are on the route from the Valles de Aragua to Portocabello.

Mount Fair-weather, Cerro de Buen Tiempo, according to Malaspina 14,710 feet high (553), in 58° 45′ N., covered with pumice, was probably still burning in recent times, like Mount Elias.

Volcano of Cook's Inlet (60° 08′ N.), according to Admiral Wrangel 12,064 feet high; regarded by that distinguished and accomplished navigator, as well as by Vancouver, as an active volcano. (554)

Mount Elias, in 60° 17′ N. and 136° 08′ W.: according to manuscripts of Malaspina found by me in the archives of Mexico, 17,851 feet high; according to the map of Captain Denham, 1853-1856, its height is only 14,968 feet.

The phænomenon seen by the Arctic voyagers in a recent expedition to the east of the mouth of Mackenzie River (in 69° 57′ N. and 127° W.), and which M'Clure called "the Volcanoes of Franklin Bay," seems to have been of the character either of what are sometimes termed "Earth-fires," or of Salses emitting hot sul-

phurous vapours. An eye-witness, the missionary Miertsching, interpreter to the expedition, found thirty or forty columns of smoke which rose from earth-fissures or from small conical elevations of clays of many colours. The smell of sulphur was so strong that one could hardly approach within twelve paces of the columns of smoke. No rock *in sitû*, or solid masses, were found. Luminous phænomena were seen at night from the ship; no eruptions of mud were observed, but great heat of the sea-bottom, and also small basins of sulphuric acid and water. The district deserves to be carefully examined. This phænomenon is not to be connected with the volcanic activity of the Californian Cascade mountains, the Cerro de Buen Tiempo, or of Mount Elias. (M'Clure, Discovery of the North-West Passage, p. 99; Papers relating to the Arctic Expeditions, 1854, p. 34; Miertsching's Reise Tagebuch, Gnadau 1855, S. 46.)

I have thus far described in their internal connection, and in ascending order, the volcanic vital activities of our planet; the great and mysterious phænomenon of the reaction of the molten interior against the surface covered with vegetable and animal organic life. Next in succession to the almost purely dynamical effects of earthquakes (of the waves of commotion), I have placed thermal springs and salses, *i. e.* phænomena which,

with or without spontaneous ignition, are produced by permanently increased temperature imparted to the waters of the springs and to gaseous exhalations, and by chemical diversity of composition. The highest, and, in its manifestations, the most complicated degree of activity is presented in volcanoes, as these elicit the great and diversified processes of cystalline rock-formation by the dry method, and are therefore not mere agents of dissolution and destruction, but are also formative, and bring substances into new combinations. A considerable portion of very recent, if not of the most recent, rocks are the work of volcanic activity; whether, as is still the case at many points of the earth's surface, by pouring forth molten masses from their own conical or dome-shaped frameworks; or whether, in the youth of our planet, basaltic and trachytic rocks may have flowed forth directly in a fluid state from a network of open fissures, in proximity to sedimentary strata.

I have endeavoured, in the preceding pages, to determine in the most careful manner the locality of the points at which communication between the fluid interior of the earth and the external atmosphere has long remained open. I have now to sum up the number of these points, to distinguish the volcanoes which still continue active from among the much greater abundance of such as have been so within remote historic periods, and to consider them in their distribution as continental and as insular volcanoes. If the entire number which I think I may assume as the lowest ("nombre limite," "limite inférieur") were *simultaneously* in a state of activity,

the influence on the constitution of the atmosphere, and on its climatic, and especially its electric, relations would assuredly be very sensible; but the non-simultaneity of the eruptions diminishes the effect and restricts it within very narrow, and for the most part merely local limits. In great eruptions there arise around the crater, in consequence of evaporation, volcanic storms, which, accompanied by lightning and violent falls of rain, often occasion devastation; but an atmospheric phænomenon of this kind has no general results. For, on account of the magnitude of the phænomenon, I have always regarded as exceedingly improbable the opinion which is even still sometimes expressed, attributing the remarkable darkness which for many months, from May to August in 1783, overspread a considerable portion of Europe and Asia as well as of the north of Africa (while on the high mountains of Switzerland the sky was seen clear and unobscured), to great volcanic activity in Iceland, and to the earthquake in Calabria. Where earthquakes embrace a wide area, a certain influence on the period of the commencement of the rainy season, as in the highlands of Quito and Riobamba in February 1797, and the south-east of Europe and Asia Minor in the autumn of 1856, may be more readily admitted, than extensive meteorological effects from an isolated volcanic eruption.

In the subjoined table the last column but one indicates the number of volcanoes which have been cited in the preceding pages; and the last column (within brackets) indicates the portion of them which have given proofs of activity within recent times.

Number of Volcanoes on the Globe.

	Pages.		
1. Europe . . .	326—328	7	(4)
2. Islands of the Atlantic .	328—332	14	(8)
3. Africa	332—334	3	(1)
4. Continent of Asia			
α. Western portion and Central Asia . .	334—342	11	(6)
β. Peninsula of Kamtschatka	342—348	14	(9)
5. East-Asiatic Islands . .	349—361	69	(54)
6. South-Asiatic Islands . .	361—367	120	(56)
7. Indian Ocean . . .	367—371	9	(5)
8. Pacific Ocean . . .	372—386	40	(26)
9. Continent of America			
a. South America.			
α. Chili . . .	273—278	24	(13)
β. Peru and Bolivia .	273—277	14	(3)
γ. Quito and New Granada . .	273—276	18	(10)
b. Central America . .	262—267	29	(18)
c. Mexico, south of the Rio Gila . . .	267—269	6	(4)
d. North-west America, north of the Gila .	388—405	24	(5)
10. Antilles ([555]) (or West-India Islands) . .	*note 555*	5	(3)
	Totals -	407	(225)

The result of this laborious investigation, which has occupied me long because I have everywhere gone back to the original authorities (the geological and geographical accounts of travellers), is that out of 407 volcanoes which have been cited, 225 have been in activity within very modern times. Earlier statements ([556]) have given the number of still active volcanoes thirty

or fifty less, because prepared on different principles. I have here restricted myself to volcanoes which either still emit vapours, or which have had historically assured eruptions within the nineteenth or the latter half of the eighteenth century. There have indeed been intervals between successive eruptions of the same volcano extending over four centuries and upwards; but such cases are very rare. We know the slow succession of great eruptions of Vesuvius, in the years 79, 203, 512, 652, 983, 1138, and 1500. Previous to the great eruption of Epomeo in Ischia in 1302, we know only of those of the years 36 and 45 B.C., therefore fifty-five years before the breaking out of Vesuvius.

Strabo, who died under Tiberius at the age of ninety, (ninety-nine years after Spartacus had intrenched himself on Vesuvius), and who had no historic knowledge of an older eruption, declares Vesuvius to be an ancient volcano which had long ago burnt out and become extinct. He says: "Above those places" (Herculaneum and Pompeii) "lies Mount Vesuios, encompassed by the finest cultivated fields, except on its summit. This is, indeed, mostly a plain surface, but unfruitful, and has an ashy appearance. It shows cleft hollows of sooty-looking rock, appearing as if it had been eaten into by the action of fire, so that we may conjecture that at some former time there burnt in these orifices a fire which has now become extinct, the fuel which supported it having been consumed." (Strabo, lib. v. page 247, Casaub.) This description does not indicate either a cone of ashes or a crater-like depression [557] of the ancient summit, the encircling ridge of

which might have served Spartacus [558] and his gladiators as a rampart.

Diodorus Siculus (lib. iv. cap. 21, 5), who lived under Cæsar and Augustus, in describing the battle of Hercules with the Giants in the Phlegræan Fields, also designates "the Mount" now called Vesuvius, as a λόφος, which, like Etna in Sicily, once emitted much fire, and (still) shows traces of ancient burning. He gives the name of Phlegræan Fields to the entire space between Cumæ and Neapolis, as does Polybius (lib. ii. cap. 17) to the still larger space between Capua and Nola; while Strabo (lib. v. p. 246) describes the district near Puteoli (Dicæarchia), where the great Solfatara is situated, with great local truth, and terms it Ἡφαίστου ἀγορά. In later times the name τὰ φλεγραῖα πεδία has been commonly limited to this district, as in the present day geologists still place the mineralogical composition of the lavas of the Phlegræan Fields in opposition to those of the district round Vesuvius. We find the same opinion, that in former times there had been fire under Vesuvius, and that that mountain had anciently had eruptions, in Vitruvius's book on Architecture (lib. ii. cap. 6), and expressed in the most decided manner in a passage which has not been sufficiently regarded. "Non minus etiam memoratur antiquitus crevisse ardores et abundavisse sub Vesuvio Monte, et inde evomuisse circa agros flammam. Ideoque nunc qui spongia sive *pumex Pompejanus* vocatur, excoctus ex alio genere lapidis, in hanc redactus esse videtur generis qualitatem. Id autem genus spongiæ, quod inde eximitur, non in omnibus locis nascitur nisi circum Ætnam et collibus Mysiæ qui a Græcis κατακεκαυμένοι nominantur." As,

according to the investigations of Böckh and Hirt, there can no longer remain any doubt as to Vitruvius having lived under Augustus [559], therefore fully a century before the eruption of Vesuvius in which the elder Pliny perished, the passage which has been quoted with the expression "pumex Pompeianus" (connecting pumice with Pompeii) presents peculiar geological interest in relation to the debated question;—whether, according to Leopold von Buch's ingenious conjecture [560], Pompeii was covered by beds of tufa containing pumice, of submarine formation, spread in horizontal strata over the whole surface between the Apennine mountains and the western coast from Capua to Sorrento and from Nola to beyond Naples, and pushed up at the first formation of the Somma;—or whether Vesuvius itself, quite contrary to its present habits, sent forth the pumice from its own interior?

Carmine Lippi [561], who (1816) ascribes the tufa which overspread Pompeii to water, as well as his acute opponent, Archangelo Scacchi [562], in the letter addressed by him to the Cavaliere Francesco Avellino (1843), have called attention to the remarkable circumstance, that a portion of the pumices of Pompeii and of the Somma enclose small pieces of lime retaining their carbonic acid, which, if they were exposed to great pressure in the course of an igneous formation, is not very surprising. I have myself had the opportunity of seeing specimens of these pumices in the interesting geological collections of my learned friend and academical colleague, Dr. Ewald. This similarity of mineralogical constitution at two opposite points must give occasion to the question, whether the covering which

overspread Pompeii was, as Leopold von Buch would consider, thrown down from the declivities of the Somma in the eruption of 79,—or whether, as Scacchi maintains, the newly opened crater of Vesuvius cast forth pumice simultaneously on Pompeii and on the Somma? The fact of "pumex Pompeianus" being known to Vitruvius in the time of Augustus, points to eruptions anterior to Pliny: and from the experience which we have had of variability in the formations by volcanic activity in different ages and under different circumstances, we are by no means warranted either in absolutely denying the possibility of Vesuvius having ever at any former period produced pumice, or in absolutely assuming that pumice, *i. e.* a fibrous or porous state of a pyrogenous mineral, can only be formed where obsidian or trachyte is present with glassy felspar (sanidine).

Although, according to the examples adduced, much uncertainty still subsists as to the length of the periods after which a slumbering volcano may re-awaken, yet it is of great importance to ascertain the geographical distribution of burning volcanoes at a determinate epoch. Of the 225 orifices through which, in the middle of the nineteenth century, the molten interior of the earth is in volcanic communication with the atmosphere, 70 (less than a third part therefore) are on continents, and 155 (or fully two thirds) are on islands. Of the 70 continental volcanoes, 53 (or three fourths) belong to America, 15 to Asia, 1 to Europe, and 1 or 2 to the portion of Africa with which we are acquainted. It is in the South-Asiatic Islands (the Sunda isles and the Moluccas) and in the Aleutian and Kurile (East-Asiatic) islands, that the greatest number of island volcanoes are congregated within the smallest space. The Aleu-

tian islands contain perhaps more volcanoes active within recent historic times than does the whole continent of South America. Taking the earth altogether, it is the region comprised between the 73rd W. and 127th E. meridian from Greenwich, and the parallels of 47° S. and 66° N., extending from south-east to north-west in the more western part of the Pacific, which is the richest in volcanoes.

If, in looking in a similarly general manner at the great sea-gulf which we are accustomed to call the Pacific Ocean, we consider it to be bounded on the north by the parallel of Bering Strait, and on the south by the parallel of New Zealand which is also that of South Chili and North Patagonia, we find,—and it is a result very deserving of notice,—that within this basin, and on the American and Asiatic shores which surround it, there are 198, or nearly seven eighths of the whole number of active volcanoes (225) on the surface of the globe. The volcanoes nearest to the poles are,—according to our present geographical knowledge,—in the northern hemisphere, the volcano of Esk, on the little island of Jan Mayen, in 71° 1′ lat., and 7° 29′ W. long., and, in the southern hemisphere, Mount Erebus, which sends forth reddish flames visible even in daylight, and which in 1841 was discovered by Sir James Ross in his great antarctic voyage ([563]), and found by him to be 12,400 feet high, or about 240 feet higher than the Peak of Teneriffe, in 77° 33′ lat. and 167° E. longitude from Greenwich.

The great comparative frequency of volcanoes on islands and on the coasts of continents, could not but early lead geologists to inquire into the causes of this phænomenon.

I have already referred, in an earlier volume (Kosmos, Bd. i. S. 454, Engl. ed. vol. i. note 234), to the complicated theory of Trogus Pompeius, under Augustus, according to which the salt water of the sea is supposed to stimulate the volcanic fire. Different chemical and mechanical causes of the influence of the neighbourhood of the sea have been adduced up to the most recent times. The ancient hypothesis of the penetration of sea-water to the volcanic hearth seemed to have acquired a more solid foundation at the epoch of Davy's discovery of the metallic bases of the earths; but the great discoverer himself soon gave up that hypothesis, to which even Gay-Lussac had been inclined ([564]) notwithstanding the rarity or entire absence of hydrogen gas. Mechanical, or rather dynamical causes, whether they should be looked for in the folding of the earth's outer crust and the upheaval of continents, or in the locally lesser thickness of that crust, would seem, according to my ideas, to present a greater degree of probability. We may readily represent to ourselves the probability that, at the margins of the upheaving continents, whose coasts now rise with more or less abruptness above the waters of the sea, simultaneously occasioned subsidence of the ocean-bed might cause the formation of fissures tending to promote communication with the molten interior. In the inland parts of elevated continents, at a distance from the oceanic areas of subsidence, there would not be the same occasion of fracture. Volcanoes follow the coast-lines in single, sometimes in double, and even triple ranges. Short cross ridges, elevated over cross fissures, connect these ranges, forming mountain-knots. Frequently, but by no means invariably, it is the outer range, nearest to the sea-shore, which is the most

active, while the more inland ones are extinct or appear approaching extinction. Sometimes persons have thought that they could recognise within one and the same range of volcanoes, an increase or decrease of eruptive activity in a definite direction, but the phænomena which are sometimes seen of a re-awakening after long periods of tranquillity render any such recognition very insecure.

As, owing either to the absence or disregard of well-assured determinations of position, both of the volcanoes themselves and of the nearest points on the sea-shore, there have been many inexact statements respecting the distance of phænomena of volcanic activity from the sea, I give here the following statements in geographical miles (sixty to an equatorial degree). In the Cordilleras of Quito, Sangay, with its unintermitting activity, is on the easternmost and most distant range, but yet it is only 112 geographical miles from the sea. Very well educated monks of the missions to the Andaquies Indians on the Alto Putumayo have assured me, that on the Upper Rio de la Fragua a tributary of the Caqueta east of the Ceja, they have seen smoke issue ([565]) from a not very high conical mountain, of which the estimated distance from the sea was 160 miles. The Mexican volcano of Jorullo, upheaved in September 1759, is eighty-four miles from the nearest point of the sea-coast (Kosmos, Bd. iv. S. 339—346, present volume, pp. 294—302); the volcano of Popocatepetl is 132 miles from the sea; an extinct volcano in the eastern cordillera of Bolivia, near S. Pedro de Cacha, in the valley of Yucay (present volume, p. 277), is above 180 miles; the volcanoes of the Siebengebirge near Bonn,

and of the Eifel (Kosmos, Bd. iv. S. 275—282, present volume, pp. 229—236) from 132 to 152 miles; those of Auvergne, the Velay, and the Vivarais (566), according to a division into three distinct groups (group of the Puy de Dôme near Clermont and the Mont-Dore; group of the Cantal; and group of the Puy and Mezenc), are respectively 148, 116, and 84 miles from the nearest sea. South of the Pyrenees, the extinct volcanoes of Olot, to the west of Gerona, with their very distinct, sometimes divided, lava-streams, are only twenty-eight miles from the Catalonian coast of the Mediterranean; on the other hand, the undoubted, and, according to all appearance only very recently extinguished, volcanoes in the long chain of the Rocky Mountains in North-west America are from 600 to 680 miles from the coast of the Pacific.

A very abnormal phænomenon in the geographical distribution of volcanoes is the existence of some which have been active within historic times, and some of which may perhaps be even still burning, in the chain of the Thian-schan (the Celestial Mountains) in Central Asia, between the two parallel chains of the Altai and the Kuen-lun. Their existence was first made known in Europe by Abel Rémusat and Klaproth; and by the aid of the sagacious and laborious sinological investigations of Stanislas Julien, I have been enabled to treat of them more fully in my Asie Centrale. (567) The distances of the volcano Pe-schan (Mont Blanc) with its lava-streams, and the still burning Mount (Ho-tscheu) of Turfan, from the shores of the Polar Sea and of the Indian Ocean, are almost equal; being about 1480 and 1520 miles. On the other hand, the volcano of Pe-

schan (whose lava-yielding eruptions, from the year 89 to the commencement of the seventh century, have been severally recorded in Chinese works) is only 172 geographical miles from the great Alpine Lake Issikul, situated on the south side of the Temurtutagh (a western portion of the Thian-schan), and 208 miles from Lake Balkasch which is 148 miles long. ([568]) The great Dsaisang Lake (near which I found myself in 1829, in Chinese Dsungary) is 360 miles from the volcanoes of the Thian-schan. There is, therefore, no deficiency of inland waters, although, indeed, not in such near proximity as that of the still active volcano of Demavend (in Persian Mazanderan) to the Caspian Sea.

If we admit that masses of water, oceanic or inland, are not requisite for the maintenance of volcanic activity, and that, as I am inclined to believe, islands and coasts are richer in volcanoes only because the upheaval effected by internal elastic forces is accompanied by adjacent depression in the bed of the sea ([569]), —so that an area of elevation borders on an area of subsidence, and at the limit between these areas great and profound clefts and fissures are occasioned,—then we may conjecture that, in the zone of Central Asia which is included between the parallels of 41° and 48° N., the great Aralo-Caspian basin of depression, as well as the considerable number of lakes (some arranged in chains and others not so arranged), may have occasioned, between the Thian-schan and the Altai Kurtschum, the existence of phænomena similar to those which elsewhere are found in proximity to the sea-coast. We know by tradition that many comparatively small pieces of water which now form chains of lakes (like beads on a necklace, *lacs à*

chapelet) were once part of a single large basin. We still see larger lakes become subdivided into smaller ones, by reason of the existing disproportion between the amount of water falling in the shape of rain or snow and the amount withdrawn by evaporation. An observer well acquainted with the Kirghis steppe, General Genz in Orenburg, thought that there once existed a water-communication between the Sea of Aral, the Aksakal, Sary-Kupa, and Tschagli. We can recognise a great furrow, running from south-west to north-east, traceable beyond Omsk between the Irtysch and the Obi, through the steppe of Barabinski with its numerous lakes, towards the moory plains of the Samoieds, Beresow, and the shore of the Icy Sea. We may perhaps connect with this furrow the old and widely prevalent tradition of a "Bitter Sea" (also called the "Dried-up Sea," Hanhai), which extended eastward and southward from Hami, and in which a part of Gobi, of which the salt and reedy centre has been recently found by the exact barometric measurements of Dr. von Bunge to be only 2558 feet above the level of the sea, rose as an island.(570) Seals, quite similar to those which inhabit the Caspian and the Baikal in troops, are found (and this is a geological fact which has not yet received the attention it deserves) in the little fresh-water lake of Oron, situated more than 400 geographical miles east of Lake Baikal. The lake of Oron, which is only some miles in circumference, is connected with the river Witim, a tributary of the Lena, in which no seals live.(571) The present isolated position of these animals, their distance from the mouth of the Volga (fully 3600 geographical miles), is a very

remarkable geological phænomenon, for it indicates a former water-communication of very extensive character. May we suppose that the many and various subsidences, to which this central part of Asia has been exposed over a wide extent, may have exceptionally given occasion, on the convexity of the continental swelling, to circumstances and relations similar to those at the borders of elevation-fissures on coasts?

Well-assured reports made to the Emperor Kanghi have made known the existence of a now extinct volcano far to the east, in the north-west part of Mantchou Tartary, in the district about Mergen, which is probably in 48½° N. lat. and 122 E. long. from Greenwich. The eruption of scoriæ and lava from this Mount Bo-schan, or Ujun-Holdongi (the Nine Hills), about fourteen miles south-west of Mergen, took place in January 1721. The hills of scoriæ which were thrown up are said, by the persons whom the Emperor Kanghi sent to examine the effects, to have occupied a space of twenty-four miles in circumference, and the same authorities stated that a current of lava, by damming up the river Udelin, occasioned the formation of a lake. From less circumstantial Chinese accounts, it would appear that Bo-schan had had an earlier igneous eruption in the seventh century. The distance from the sea is about 420 geographical miles; more than three times the distance of the volcano of Jorullo from the sea, and similar to that of the Himalaya. ([572]) We owe these interesting notices to W. P. Wassiljew (Geograph. Bote, 1855, Heft 5, S. 31); and to a paper by Semonow (the learned translator of Carl Ritter's Erdkunde), in the 17th volume of the Memoirs of the Russian Imperial Geographical Society.

In inquiries respecting the geographical distribution of volcanoes, and their greater frequency on islands and coasts (*i. e.* margins of elevation of continents), the probable great inequality of the already attained thickness of the earth's crust has also been brought into discussion. One is inclined to assume the surface of the interior molten mass to be nearer the points where volcanoes have broken forth. But inasmuch as we can imagine many intermediate degrees of consistency in the solidifying materials, it is difficult to form any clear conception of such a supposed surface of the molten mass, if we are to look for the principal cause of all overthrowals, fissurings, elevations, and basin-shaped subsidences, in an alteration of capacity in the external already solidified shell. If it were admissible to determine the so-called thickness of the solid crust of the globe ([573]) from the data we have obtained in Artesian wells and the temperature of fusion of granite, by an arithmetical series, *i. e.* by assuming throughout equal geothermic gradations of depth, we should find it not quite twenty-one geographical miles, or $\frac{1}{329}$th of the polar diameter ([574]); but the effects of pressure and of conduction of heat in different kinds of rock give us reason to suppose that the increment of heat in descending will become less rapid as the depth increases.

Notwithstanding the very small number of points at which the molten interior of our planet is at the present time in active communication with the atmosphere, it is yet a question not without importance if we ask, what is the kind and the measure of influence exercised by volcanic gaseous exhalations on the chemical compo-

sition of the air, and through its medium upon the development of organic life upon the Earth's surface? We must first bring under consideration, in reference to this question, the circumstance that gases are exhaled less from summit-craters themselves, than from small cones of eruption and from the fumaroles which over wide spaces surround so many volcanoes; and that even entire districts, in Iceland, in the Caucasus, in the highlands of Armenia, in Java, the Galapagos, the Sandwich Islands, and New Zealand, manifest uninterrupted activity through solfataras, naphtha-springs, and salses. Volcanic districts which are now reckoned as extinct are also to be regarded as sources of gas, and it is probable that the silent operation of subterranean decomposing and formative forces taking place in them is, in respect to quantity, more productive than the grander but more rare phænomena of volcanic eruptions; although, in regard to these also, it is to be remembered that the "fields of lava" continue for years to send forth visible and invisible vapours. If it should be thought that the effects of these small chemical processes may be disregarded, because the enormous volume of the atmosphere, incessantly impelled to and fro by currents, can be so little altered by the addition to its primitive mixture of such minute fractions appearing severally so unimportant ([575]), we should remember the powerful influence exercised, according to the fine investigations of Percival, Saussure, Boussingault, and Liebig, by three or four ten-thousandth parts of carbonic acid gas in our atmosphere upon the existence of vegetable organic life. According to Bunsen's fine investigations on the volcanic gases, some fumaroles, in different stages

of activity, and under different local circumstances, give out (for example, at Hecla) 0·81 to 0·83 of nitrogen, and in the lava-streams of that mountain 0·78, with only traces (0·01 to 0·02) of carbonic acid gas; other fumaroles in Iceland, as near Krisuvik, give 0·86 to 0·87 of carbonic acid, with scarcely so much as 0·01 of nitrogen. ([576]) In the same manner the important investigations into the emanations of gas in Southern Italy and in Sicily, by Charles St. Claire Deville and Bornemann, show great amount of nitrogen (0·98) in the exhalations from a cleft deep within the crater of Vulcano, but they also show sulphuric acid vapours with a mixture of 74·7 parts of nitrogen and 18·5 oxygen; not differing much, therefore, from the constitution of atmospheric air. The gas which rises in the fountain of Acqua Santa ([577]) near Catania is on the other hand pure nitrogen, as was at the time of my American journey the gas of the Volcancitos de Turbaco. ([578])

Are we to suppose that the large quantity of nitrogen which is diffused by volcanic activity is solely that which is brought to the volcanoes by meteoric water? or are ther in the interior deeply situated sources of nitrogen? It is also to be remembered that the air contained in rain-water, instead of 0·79, as our common air, has, according to my experiments, only 0·69 of nitrogen. The latter is a source of enhanced fertility by the formation of ammonia through the operation of electric explosions, which are of almost daily occurrence within the tropics. ([579]) The influence of nitrogen on vegetation is similar to that of the substratum of atmospheric carbonic acid.

Boussingault, in his analysis of gases from volcanoes

near the equator (Tolima, Puracé, Pasto, Tuqueres, and Cumbal), found, together with much aqueous vapour, carbonic acid and sulphuretted hydrogen, but no muriatic acid, no nitrogen, and no free hydrogen. ([580]) The influence which the interior of our planet still exercises on the chemical composition of the atmosphere, by withdrawing these substances to return them again under other forms, is no doubt a very inconsiderable part of the chemical revolutions which, in primeval times, the atmosphere must have undergone at the breaking forth of great mountain masses from open fissures. The conjectures which have been formed respecting the probably very large portion of carbonic acid gas in the ancient atmosphere, have been strengthened by the comparison of the thickness of coal deposits with the very thin carboniferous stratum (only seven lines in thickness), which, in the temperate zone, according to Chevandier's calculations, our thickest forests would supply to the ground in 100 years. ([581])

In the infancy of geology, prior to Dolomieu's sagacious conjectures, the source of volcanic activity was not placed beneath the oldest rocks, which were then universally held to be granite and gneiss. Resting on some feeble analogies of inflammability, it was long believed that the source of volcanic eruptions, and of the emanations of gas occasioned by them, and lasting for many centuries, was to be sought for in the combustible materials contained in the newer upper silurian sedimentary strata. More general knowledge of the earth's surface, more profound and better directed geological researches, and the beneficial influence which the great advances of modern chemistry have exercised

on geology, have taught us that the three great groups of volcanic or eruptive rocks (trachytes, phonolites, and basalts), which, regarded in great masses, are different from each other in age, and most often occur very widely apart, are, however, all three more recent in their appearance than the plutonic granites, diorites, and quartzose porphyries, and than all silurian, secondary, tertiary, and quartary (pleistocene) formations; and that they even often intersect loose beds of diluvial gravel and ossiferous breccias. Rozet has made the important remark, that a striking multiplicity ([582]) of such intersections are found congregated together within a small space in Auvergne; for if the great trachytic mountain masses of the Cantal, Mont Dore, and Puy de Dôme break through granite itself, and sometimes (as between Vic and Aurillac, and at the Giou de Mamon) enclose large fragments of gneiss ([583]) and limestone, yet we also see trachyte and basalt intersect as dikes, gneiss, carboniferous rocks, tertiary and diluvial strata. Basalts and phonolites, which are nearly allied to each other (as is shown by the Bohemian Mittelgebirge and Auvergne), are both later formations than the trachytes, which are often intersected by dikes of basalt.([584]) Phonolites are older than basalts, in which they have never been found forming dikes, whereas dikes of basalt often traverse porphyritic schists (phonolites). In the Andes of Quito I found the basalts locally separated from the prevailing trachytes, occurring almost alone at the Rio Pisque and in the valley of Guaillabamba. ([585])

As in the volcanic high plain of Quito everything is covered over by trachytes, trachyte conglomerates, and tufa, my most earnest endeavours were bent to discover

some point at which it might be clearly seen what was the older rock upon which the mighty cones and bell-shaped mountains rose, or, more properly speaking, through which they had broken forth. I was so fortunate as to find such a point, at a height of 9483 feet above the Pacific, in the month of June 1802, when attempting, from Riobamba Nuevo, the ascent of Tungurahua, on the side of the Chuchilla de Guandisava. I was proceeding from the pleasantly situated village of Penipe, by the oscillating rope-bridge (puente de maroma) over the Rio Puela, to the solitary Hacienda de Guansce (7929 feet), where, on the south-east, opposite to the junction of the Rio Blanco with the Rio Chambo, a magnificent colonnade of black, pitchy-looking trachyte rises to view. The appearance recalls that of the basaltic quarry at Unkel seen from a distance. On the Chimborazo, rather above the little lake of Yana Cocha, I saw a similar, loftier, but less regular columnar group of trachyte. The columns to the south-east of Penipe are, for the most part, five-sided, only 15 inches in diameter, and often bent and diverging. At the foot of these pitch-black Penipe trachytes (not far from the mouth of the Rio Blanco), one sees a phænomenon very unlooked for in this part of the Cordilleras, viz., greenish-white mica-slate, with interspersed garnets; and, farther on (beyond the shallow little stream of Bascaguan, by the Hacienda of Guansce, near the bank of the Rio Puela), probably dipping under the mica-slate, granite of a middling-sized grain, with bright reddish felspar, a little blackish-green mica, and much grayish-white quartz. Hornblende is wanting. It is not syenite. The trachytes of the volcano of Tungurahua, which in

their mineralogical constitution are like those of Chimborazo, *i.e.* consist of a mixture of oligoclase and augite, have thus here broken through granite and mica-slate. Farther to the south, a little to the east of the route from Riobamba Nuevo to Guamote and Ticsan, what were formerly called the primitive rocks, mica-slate and gneiss, come everywhere into view in the Cordillera, which has here turned away from the sea, appearing about the foot of the colossal Altar de los Collanes, of Cuvillan, and of the Paramo del Hatillo. Before the arrival of the Spaniards, and even before the sovereignty of the Incas extended so far to the north, the natives are supposed to have worked some metalliferous beds near the volcano. A little to the south of San Luis, many dikes of quartz may be observed traversing a greenish clay-slate. Near Guamote, at the entrance of the grassy plain of Tiocara, we find great masses of quartzite, very poor in mica, of remarkably linear parallel structure, inclining regularly 70° to the north. More to the south, near Ticsan, not far from Alausi, the Cerro Cuello de Ticsan presents great masses of sulphur in a bed of quartz, subordinate to the adjacent mica-slate. Such an extensive distribution of quartz in the vicinity of trachytic volcanoes at first sight excites some surprise. But my observations of the superposition, or rather, of the breaking forth of trachyte through mica-slate and granite at the foot of Tungarahua (a phænomenon which is as rare in the Cordilleras as it is frequent in Auvergne), have been confirmed, 47 years later, by the excellent researches of the French geologist, Sebastian Wisse, at Sangay. This colossal volcano, 1343 feet higher than Mont Blanc,

having no lava-streams (Charles Deville considers the equally active volcano of Stromboli to be similarly without such), but which, at least since the year 1728, has been in constant activity, erupting black and often brightly-glowing rocks and stones, forms an island of trachyte, of scarcely so much as 8 miles diameter ([586]), in the midst of granite and gneiss. Very different relations of position are presented, as I have already remarked, in the volcanic district of the Eifel, in the Maars (mine-funnels) sunk in the Devonian schists, as well as in the lava-yielding volcanic frameworks of the long ridges of the Mosenberg and Gerolstein. The surface does not here betray what is concealed within. The absence of trachyte, in volcanoes which were so active many thousand years ago, is a still more striking phænomenon. The augite-containing scoriæ of the Mosenberg, which in part accompany the basaltic lava-stream, have embedded in them small burnt pieces of schist, not fragments of trachyte; there are no trachytes in the vicinity. This last-named rock is only visible in the Eifel district ([587]), quite apart and at a distance from Maars and lava-yielding volcanoes, as in the Sellberg, near Quiddelbach, and in the ridge of Reimerath. The variety of formations broken through by volcanoes, in rising through the upper crust of the earth, are geologically no less important than are the substances which they produce.

In the most distant parts of the earth the forms of the rocky frameworks through which the volcanic activity manifests itself, or has striven to do so, have been far more carefully examined and represented in their often very complicated diversity, than was the

case in the last century, when the whole morphology of volcanoes was limited to cones and domes or bell-shaped mountains. We are now most satisfactorily acquainted with the structure, hypsometry, and arrangement (with what the ingenious Carl Friedrich Naumann calls the "geotektonik") ([588]) of many volcanoes, while we are still in great uncertainty respecting the composition of their rocks, and respecting the association of mineral species which characterise their trachytes, and can be recognised apart from the ground mass. Both these kinds of knowledge, however, — the "morphological" for the rocky frameworks, and the "oryctognostical" for their composition, — are alike necessary for forming a complete judgment in respect to volcanic activity; indeed, the latter kind, based on crystallisation and chemical analysis, may be regarded as the more geologically important of the two, on account of the connection with plutonic rocks (quartzose-porphyry, greenstone, and serpentine). All the little which we suppose we know of what we call volcanic character in the moon is, from the nature of the case, restricted solely to form. ([589])

If, as I hope, any interest attaches to what I have here said respecting the classification of volcanic rocks, or rather respecting the division of trachytes according to their composition, the merit of the grouping belongs entirely to my friend and Siberian travelling companion, Gustav Rose. By his own observations in the open field over extensive regions, and by a happy combination of knowledge in chemistry, crystallographic mineralogy, and geology, he has been peculiarly well qualified for promulgating new views respecting the

minerals, whose varied, yet often repeated association is the result of volcanic activity. He has, partly out of kindness to myself, and at my solicitation, particularly since 1834, repeatedly examined the specimens which I brought back with me from the volcanoes of New Granada, Los Pastos, Quito, and the high land of Mexico, and has compared them with those brought from other parts of the world, which are contained in the rich mineralogical collection of Berlin. Leopold von Buch, when he was in Paris, in 1810—1811, between his return from Norway and his departure for Teneriffe, at a time when my collections had not been separated from those of my companion, Aimé Bonpland, had examined them microscopically with persevering diligence. He had also previously, while with Gay-Lussac in Rome, in the summer of 1805, and afterwards in France, taken into consideration what I had written down at the time and on the spot, in my travelling journal, both respecting particular volcanoes and in general (in July 1802) "Sur l'affinité entre les volcans et certains porphyres dépourvus de quartz."(590) I preserve, as a valued memorial, some pages with remarks on the volcanic products of Quito and Mexico, which that great geologist wrote for my information more than 46 years ago. Since, as I have elsewhere explained more circumstantially(591), travellers can but carry forward the incomplete knowledge of their own time, and their observations are liable to be deficient in many of the guiding ideas and of the distinguishing marks which are the fruits of progressive knowledge, a time may arrive when the materials they have collected and arranged geographically will almost alone retain a value.

If, as has often been done, it is desired to restrict the name of trachyte (for the sake of conformity with its earliest application to the rocks of Auvergne and of the Siebengebirge near Bonn,) by applying it exclusively to a volcanic rock containing felspar (particularly Werner's glassy felspar and Rose's and Abich's sanidine), the result is unfruitfully to rend asunder those intimate links between different volcanic rocks which conduct to higher geological views. Such a restriction might justify the expression, "that Etna, rich in labradorite, has no trachyte; and, according to it, my own collections would be held to prove that "none of the almost countless volcanoes of the Andes consist of trachyte, and even that the mass of which they are composed should be called Albite, and, therefore, inasmuch as at that time (1835) all oligoclase was erroneously supposed to be albite, that all volcanic rocks would have to be designated by the general name of Andesite (consisting of albite with little hornblende)."([592]) The impressions which I brought back from my travels of that which, notwithstanding diversity of mineralogical composition, all volcanoes possess in common, have been confirmed by Gustav Rose, who, in accordance with the views and evidence unfolded in his fine memoir on the felspathic group([593]), has, in his classification of trachytes, regarded orthoclase, sanidine, the anorthite of the Somma, albite, labradorite, and oligoclase, in a general point of view, as the felspathic portion of volcanic rocks.

Short denominations, purporting to contain definitions, often tend in various ways, in the study of rocks as well as in chemistry, to produce obscurity and not unfrequently confusion. I was myself for some time

inclined to use the expressions orthoclase-trachytes, labrador-trachytes, oligoclase-trachytes, and thus to include glassy felspar (sanidine), on account of its chemical composition, in the genus orthoclase (common felspar). The names were well-sounding and simple; but their simplicity was itself misleading; for, if the term labrador-trachyte would correctly lead us to Etna and Stromboli, that of oligoclase-trachyte, in its important twofold connection with augite and hornblende, would falsely connect together the widely distributed, very different formations of Chimborazo and the volcano of Toluca. It is the association of a felspathic element with one or two others, which here, as in the case of certain dike formations, presents itself as the characteristic indication.

The following classification of trachytes, distinguished according to the crystals which are found enclosed in them, has been made by Gustav Rose since the winter of 1852. The principal results of this work, in which oligoclase is never confounded with albite, were attained by him 10 years before, when, in his geological examinations in the Riesengebirge, he found that oligoclase was there an essential ingredient in the granite; and his attention being thus directed to the importance of oligoclase as an essential constituent, he sought for it also in other rocks.([594]) This examination conducted him to the important result that albite is never a constituent of a particular kind of rock. (Poggend. Ann. Bd. lxvi. 1845, S. 109.)

First Division. — "The ground-mass contains only crystals of glassy felspar; these are in the form of tablets, and are usually large. Hornblende and mica

are either entirely absent, or, at the utmost, occur only sparingly, and are wholly unessential ingredients. To this division belong the trachytes of the Phlegræan Fields (Monte Olibano, near Pozzuoli), of Ischia, and of La Tolfa, and also of a portion of the Mont Dore (Grande Cascade). Augite shows itself in small crystals in trachytes of the Mont Dore, but only very rarely [595]; in the Phlegræan fields, with hornblende, not at all; nor does leucite, of which, however, some pieces were collected by Hoffmann above the Lago Averno (on the road to Cumæ), and some by myself on the declivity of the Monte Nuovo [596], in the autumn of 1822. Leucite-ophyr, in loose pieces, is more plentiful in the island of Procida and the neighbouring Scoglio di S. Martino."

Second Division. — "The ground-mass contains detached crystals of glassy felspar and a quantity of small snow-white crystals of oligoclase. The latter are often intermingled with the glassy felspar, and form a veil round the felspar, as is often the case in Gustav Rose's 'granitite' (the rock which forms the main mass of the Riesen- and Iser-gebirge, granite, with red felspar, particularly rich in oligoclase and magnesia-mica; but without any white potassa mica). Hornblende and mica, and, in some varieties, augite, sometimes present themselves in small quantities. To this class belong the trachytes of the Drachenfels and Perlenhardt in the Siebengebirge near Bonn [597], and many varieties of the rocks of Mont Dore and Cantal: also several trachytes in Asia Minor (of which we owe the knowledge to Pierre von Tschichatscheff), at Afiun Karahissar (celebrated for the culture of the poppy), Mehammed Kjoe

in Phrygia, and Kajadschyk and Donanlar in Mysia, in which glassy felspar, much oligoclase, some hornblende, and brown mica are intermixed."

Third Division.—"The ground-mass of this dioritic trachyte contains many small crystals of oligoclase with black hornblende and brown magnesia-mica. To this division belong the trachytes of Ægina ([598]), of the Kozelnik valley near Schemnitz ([599]), of Nagyag in Transylvania, of Montabaur in the Duchy of Nassau, of Stenzelberg and of the Wolkenburg in the Siebengebirge near Bonn, of Puy de Chaumont near Clermont in Auvergne, and of Liorant in the Cantal; Kasbegk in the Caucasus, the Mexican volcanoes of Toluca ([600]) and Orizaba, the volcano of Puracé, and, although it is very uncertain whether these latter are trachytes, the magnificent columns of Pisoje ([601]) near Popayan. Von Buch's 'domites' also belong to this division. In the white fine-grained ground-mass of the trachytes of the Puy de Dôme there are glassy crystals which have always been taken for felspar, but which are most distinctly streaked in the plane of cleavage, and are really oligoclase; hornblende and some mica are found with them. According to the volcanic specimens for which the royal collection is indebted to Herr Möllhausen, the draftsman and topographér of Lieutenant Whipple's exploring expedition, we should also regard, as belonging to this third division, or to the dioritic Toluca trachytes, those of Mount Taylor, between Santa Fè del Nuevo Mexico and Albuquerque, as well as those of Cieneguilla on the western slope of the Rocky Mountains, where, according to the fine observations of Jules Marcou, black lava-streams are seen to have flowed over the

Jurassic formation." The same mixtures of oligoclase and hornblende which I have seen in the Aztec highlands (in Anahuac properly so called), but not in the Cordilleras of South America, are also found far to the westward of the Rocky Mountains and of Zuñi, near the Mohave River, a tributary of the Rio Colorado. (See Marcou, "Résumé of a Geological Reconnaissance from the Arkansas to California, July 1854," pp. 46—48; and also two important French Memoirs entitled, "Résumé explicatif d'une Carte Géologique des Etats-Unis, 1855," pp. 113 and 116, and "Esquisse d'une Classification des Chaînes de Montagnes de l'Amérique du Nord, 1855;" "Sierra de San Francisco et Mount Taylor," p. 23.) Among specimens from Java, which I owe to the kindness of Dr. Junghuhn, we have also recognised trachytes belonging to the "third division," from three volcanic districts; those of Burung-agung, Tjinas, and Gunung Parang (in Batugangi).

Fourth Division.—"The ground-mass contains augite with oligoclase. To this division belong the Peak of Teneriffe ([602]), the Mexican volcanoes Popocatepetl ([603]), and Colima; the South-American volcanoes Tolima (with the Paramo de Ruiz), Puracé near Popayan, Pasto and Cumbal (according to the fragments collected by Boussingault), Rucu-Pichincha, Antisana, Cotopaxi, Chimborazo ([604]), Tungurahua, and the trachyte-rocks which are covered with the ruins of old Riobamba. In Tungurahua we also find, with the augites, some blackish green uralite crystals, from half a line to five lines long (from about one twentieth of an inch to half an inch), with perfect augite-shape and the planes of cleavage of hornblende. (See Rose, Reise nach dem Ural, Bd. ii.

S. 353.) I brought such a piece with distinct uralite crystals back with me from a height of 13,300 feet on the side of Tunguragua. In Gustav Rose's opinion, it is strikingly different from the seven trachyte fragments from the same volcano which are in my collection, and reminds him of the formation of schistose augitic porphyry which we found so extensively on the Asiatic slope of the Ural. (See the last-quoted work, Bd. ii. S. 544.)

Fifth Division.—"A mixture of labradorite (605) and augite (606); a doleritic trachyte. Etna, Stromboli, and, according to the excellent examination of the trachytes of the Antilles by Charles Sainte-Claire Deville, the Soufrière de la Guadeloupe, and on Bourbon the three great 'Cirques' which surround the Pic de Salazu."

Sixth Division.—"An often-grey 'ground-mass,' in which there are crystals of leucite and augite with very little olivine: Vesuvius and Somma; also the extinct volcanoes of Vulturo, Rocca Monfina, the Alban Hills and Borghetto. In the older masses, (for example in the masonry and pavement of Pompeii,) the leucite crystals are of considerable size and more abundant than the augite. On the other hand in the present lavas the augites prevail, and generally speaking leucites are very rare. Nevertheless the stream of lava of April 22, 1845, furnished them in large quantities. (607) Fragments of trachytes belonging to the first division, containing glassy felspar (Leopold von Buch's 'trachytes proper'), are found imbedded in the tufas of Monte Somma; and also singly beneath the layer of pumice which covers Pompeii. The leucite-ophyr trachytes of this sixth division are to be carefully distinguished from

the trachytes of the first division, although, as has been already noticed, leucites also occur in the westernmost parts of the Phlegræan Fields and on the island of Procida."

The ingenious author of the classification of volcanoes which has been here introduced, in which they are classed according to the association of simple minerals which they present, by no means considers that he has exhausted the grouping of all that the surface of the earth (still so exceedingly imperfectly explored in a scientifically geological and chemical sense) can offer. Alterations in the nomenclature of the associated minerals, as well as an augmentation of our list of trachyte formations, are to be expected in two ways: by the progressive improvement of mineralogy (in more accurate specific distinction, at once according to form and according to chemical composition), and by the augmentation of our collections, which are in most cases still so incomplete and so little suited for the desired objects. Here, as everywhere, when in cosmical considerations the knowledge of the governing laws has to be attained through a widely comprehensive comparison of particulars, we must proceed from the fundamental principle that all that we think we know in the present state of the sciences is but a poor instalment of that which the next century will present. A variety of means are now at hand for accelerating the acquisition of such fuller knowledge; but there is still great deficiency, as regards the application of thoroughly exhausting methods of examination, in the exploration which has hitherto been made of the trachytic portion of the upheaved, sunken, or fissure-opened surface of the part of the earth which is not covered by the ocean.

Volcanoes which are very near to each other, and which are similar in form, construction of framework, and "geotechtonic" relations, have often a very different individual character in the composition and association of their mineral aggregates. On the great cross fissure which, running almost due east and west from sea to sea, intersects a south-east and north-west mountain chain (or more truly an uninterrupted mountainous swelling),—the volcanoes are arranged in succession thus: Colima (13,003 feet), Jorullo (4265 feet), Toluca (15,168 feet), Popocatepetl (17,726 feet), and Orizaba (17,374 feet). The volcanoes which stand next to each other are dissimilar in characteristic composition; the trachytes of the alternate ones are similar. Colima and Popocatepetl consist of oligoclase with augite (therefore have the Chimborazo or Teneriffe trachyte); Toluca and Orizaba consist of oligoclase with hornblende (therefore have the Ægina and Kozelnik rock). The late upheaved volcano of Jorullo, which can scarcely be regarded as more than a great "hill of eruption," consists almost solely of basaltic and pitchy, mostly scoriaceous lavas, and seems to be nearer to the Toluca than to the Colima trachyte.

In these considerations on the diversity of mineralogical constitution between neighbouring volcanoes, we may at once see a censure of the unfortunate attempt to introduce, as the name for a kind of trachyte, a designation taken from a chain of mountains, in great part volcanic, extending over a distance of 7200 geographical miles. The name of "Jura-limestone," which I was the first to introduce ([608]), is not objectionable, because it is taken from a simple, unmixed kind

of rock, and from a chain whose age is indicated by the superposition of organic imbedded fossils; nor is there any objection to names taken from individual mountains, or to the use of such expressions as "Teneriffe-" or "Etna-trachytes" for particular oligoclase or labradorite formations. While there was a disposition to recognise everywhere among the very different kinds of felspar belonging to the trachytes of the Andes the presence of albite, every rock in which it was supposed to occur was termed "Andesite." I first find this name with the positive definition, "Andesite is formed by predominating albite and some hornblende," in an important memoir of Leopold von Buch, in 1835, "On Craters of Elevation and Volcanoes."(609) This disposition to see albite everywhere lasted for five or six years, until, in mpartially renewed and more thorough examinations, the trachytic albites were recognised as oligoclase. (610) Gustav Rose has arrived at doubting whether albite presents itself at all in these rocks as an essential ingredient; and thus Andesite, according to the older view of its character, would be wanting in the chain of the Andes itself.

The mineralogical constitution of trachytes is imperfectly discerned when the porphyritically imbedded crystals are not capable of being detached from the ground-mass so as to be separately examined and measured, and when it is necessary to have recourse to the numerical proportions of the earths, alkalies, and metallic oxides, as given by analysis, and to the specific gravity of the apparently amorphous mass which has to be analysed. The desired result is obtained in a more convincing and certain manner when both the ground-

mass itself and its contents can be separately examined, both oryctognostically and chemically. This is the case, for example, in the trachytes of the Peak of Teneriffe, and in those of Etna. The assumption that the ground-mass consists of the same minute undistinguishable constituents which we recognise in the large crystals, appears by no means solidly established; for, as we have already seen above, in Charles Deville's ingeniously executed investigations, the apparently amorphous ground-masses for the most part furnish more silicic acid than would be expected from the felspar and other visible ingredients. In leucite-ophyrs, as Gustav Rose remarks, a striking contrast shows itself in the specific differences of the prevailing alkalies, *i. e.* those of the inwoven potassa-containing leucites, and of the ground-mass which contains almost solely soda.(611)

But besides these associations of augite with oligoclase, augite with labradorite, and hornblende with oligoclase, which have been instanced in the above assumed classification of trachytes, and by which they are specially characterised, we find in each volcano other easily recognisable non-essential ingredients, whose frequency or constant absence in different but often neighbouring volcanoes is remarkable. It is probable that this fact of the frequent occurrence of a particular ingredient, or of its having only appeared at widely separated intervals of time, has depended on a variety of conditions, such as the depth at which the substances have originated, temperature, pressure, degree of fluidity, and slow or rapid cooling. The specific association or absence of particular ingredients is opposed to certain theories; for example, to the supposed origin of pumice

from glassy felspar or from obsidian. These considerations — which are by no means peculiar to very recent times, having been touched upon towards the close of the 18th century in reference to the comparison of the trachytes of Hungary with those of Teneriffe — engaged my earnest attention for several years, as appears from my journals kept in Mexico and among the Andes. Since that period great advances have been made in lithology, and the less perfect determinations of mineral species which I was then able to make have been either corrected, or established on more secure foundations, by Gustav Rose's long-continued examination and discussion of my collections.

Mica.

Black or dark-green magnesia-mica is very frequent in the trachytes of Cotopaxi, at a height of 14,470 feet, between Suniguaicu and Quelendaña, as well as in the subterranean pumice-stone quarries of Guapulo and Zumbalica, 16 miles from the foot of the volcano. ([612]) The trachytes of the volcano of Toluca are also rich in magnesia-mica, which is wanting at Chimborazo. ([613]) In our continent, micas have presented themselves in abundance: at Vesuvius (for example, in the eruptions of 1821—1823, according to Monticelli and Covelli); in the Eifel in the ancient volcanic bombs of the Lacher See ([614]); in the basalt of Meronitz, of the marly Kausawer-Berg, and especially of the Gamayer-Kuppe ([615]) in the Bohemian Mittelgebirge; and, more rarely in phonolite ([616]), as in the dolerite of the Kaiserstuhl, near Freiburg. It is a remarkable circumstance, that in the trachytes and lavas of both continents

no white (mostly biaxial) potassa-mica, but only dark-coloured (mostly uniaxial) magnesia-mica, appears to have been produced; and that this exclusive occurrence of magnesia-mica extends to many other eruptive and plutonic rocks, basalt, phonolite, syenite, syenite-slate, and even to granitite; while granite proper contains simultaneously white potassa-mica and black or brown magnesia-mica. ([617])

Glassy Felspar.

This kind of felspar, which plays so important a part in the activity of European volcanoes, in the trachytes of the first and second divisions (for example, at Ischia, in the Phlegræan Fields, and in the Siebengebirge near Bonn), is probably wholly wanting in the New Continent in the trachytes of active volcanoes; which is the more striking, inasmuch as sanidine (glassy felspar) belongs essentially to the argentiferous non-quartzose Mexican porphyries of Moran, Pachuca, Villalpando, and Acaguisotla, of which the first are connected with the obsidians of Jacal. ([618])

Hornblende and Augite.

In the preceding account of the characteristics of the six different divisions of trachytes, it was remarked that the same mineral species which appear as essential ingredients or constituents in some divisions (as, for example, hornblende, in the third division, or Toluca rock), appear in other divisions (*e. g.* in the fourth and fifth, the Pichincha and Etna rocks) only sporadically. I have found hornblende, though not abundantly, in the trachytes of the volcanoes of Cotopaxi, Ruca-Pichincha,

Tungurahua, and Antisana, by the side of augite and oligoclase; but on Chimborazo, up to a height of above 19,000 feet, I scarcely found any hornblende at all with those two minerals. Of the many specimens brought home from Chimborazo, hornblende has only been recognised in two, and in those only in small quantity. In the eruptions of Vesuvius in 1822 and 1850, augite and hornblende crystals (the latter attaining a length of between seven and eight tenths of an inch) were formed contemporaneously by exhalations of vapours in fissures. ([619]) On Etna, as Sartorius von Waltershausen has remarked, hornblende belongs more particularly to the older lavas. As the remarkable mineral which Gustav Rose has called uralite, and which is widely diffused in Western Asia and in several parts of Europe, is nearly allied by structure and the form of its crystals to hornblende and augite ([620]), I would here notice that uralite crystals have been recognised for the first time as belonging to the New Continent, by having been discovered by Rose in a piece of trachyte which I knocked off on the declivity of Tungurahua, 3200 feet below the summit.

Leucite.

Leucites — which in Europe belong exclusively to Vesuvius, the Rocca Monfina, the Alban Hills near Rome, the Kaiserstuhl in the Breisgau, and the Eifel (on the western side of the Lacher See they are found in blocks, not in the rock in situ, as on the Burgberg, near Rieden)— have never been found in the volcanic mountains of the New Continent and the Asiatic portion of the old. Leopold von Buch had discovered, so long

ago as 1798, that they often form round a crystal of augite, and had described this in an excellent memoir. ([621]) The augite crystal around which, according to the remark of that great geologist, the leucite forms is seldom wanting, but yet appears to be occasionally replaced by a little nucleus or morsel of trachyte. The unequal degree of fusibility between the kernel and the surrounding leucite mass opposes some chemical difficulties to the explanation of the mode of formation within the envelope. Leucites, in part detached, according to Scacchi, and in part intermixed with the lava, were extremely abundant in the eruptions of Vesuvius in 1822, 1828, 1832, 1845, and 1847.

Olivine.

Olivine is very frequent in the old lavas of Vesuvius ([622]), particularly in the leucite-ophyrs of the Somma; in the Arso of Ischia, in the eruption of 1301, mingled with glassy felspar, brown mica, green augite, and magnetic iron; in the Eifel volcanoes which have sent forth lava-streams (*e. g.* in the Mosenberg, west of Manderscheid) ([623]); and in the south-east part of Teneriffe, in the lava-eruption of Guimar in 1704; but I have sought for it zealously, but in vain, in the trachytes of the volcanoes of Mexico, New Granada, and Quito. Our Berlin collections contain from only four volcanoes, —Tungurahua, Antisana, Chimborazo, and Pichincha,— 68 pieces of trachyte, 48 of which were brought home by myself, and 20 by Boussingault. ([624]) In the basaltic formations of the New Continent, olivine occurs as frequently near augite as in Europe; but the black basalt-

like trachytes of Yana-Urcu, near Calpi, at the foot of Chimborazo ([625]), as well as those belonging to what is called "la reventazon del volcan de Ansango," ([626]) contain no olivine. It was only in the great brownish-black lava-stream, with a curled scoriaceous surface and cauliflower-like intumescence, up which we made our way to the crater of the volcano of Jorullo, that we found small grains of olivine. ([627]) The very general scarcity of this mineral in the more recent lavas and in the greater part of the trachytes, becomes less surprising when we remember that, however essential olivine may appear to be, yet (according to Krug von Nidda and Sartorius von Waltershausen) there are in Iceland and in the German Rhöngebirge basalts without olivine, which can scarcely be distinguished from the basalts having olivine. In earlier times it was usual to call the former "trap" and "wacke," and in more recent times, "anemasite." ([628]) Olivines, which are sometimes found as large as a man's head in the basalts of Rentières in Auvergne, also attain, in the Unkel quarries, which were the subject of my first youthful studies, a diameter of more than 6 inches. The fine often-polished hypersthene of Elfdal in Sweden, a granular mixture of hypersthene and labradorite, which Berzelius has described as syenite, also contains olivine ([629]), as does (a still more rare case) the phonolite of the Pic de Griou ([630]) in the Cantal. According to Stromeyer, olivine is very constantly accompanied by nickel; and Rumler has discovered in it arsenic ([631]), a metal which has very recently been found to be widely distributed in mineral springs and even in sea-water. I have spoken earlier of the occurrence of olivine in meteoric

stones (aerolites)([632]), and in artificial scoriæ (slags) ([633]), examined by Sefström.

Obsidian.

So long ago as the spring and summer of 1799, when I was preparing in Spain for my voyage to the Canaries, the belief of the formation of pumice solely from obsidian prevailed generally among the mineralogists of Madrid,—Hergen, Don José Clavijo, and others. This belief had been based on the study of fine geological collections from the Peak of Teneriffe, as well as on the comparison with phenomena in Hungary, although the latter had then been for the most part represented according to the interpretation resulting from the Neptunian views of the Freiberg school. Doubts as to the insufficiency of this theory of the formation of pumice, which were very early awakened in me by my own observations in the Canaries, in the Cordilleras of Quito, and in the range of the Mexican volcanoes ([634]), incited me to direct my most earnest attention to two groups of facts: one being the general diversity of the substances *enclosed* in obsidians and in pumice-stones; and the other their frequency of association or entire separation in well-examined active volcanic frameworks. My journals are filled with data on this subject; and my determinations of the species of the minerals forming part of the rocks have since been assured by the recent and varied examinations of my ever kind and ready friend Gustav Rose.

In obsidian, as in pumice, glassy felspar is found as well as oligoclase, and often both together. I may adduce, as examples, the Mexican obsidians collected by

me from the Cerro de las Navajas, on the eastern declivity of Jacal; those of Chico with many crystals of mica; those of Zimapan, S. S.W. of the city of Mexico, with distinct, interspersed, small quartz crystals; the pumices of the Rio Mayo (on the mountain-path from Popayan to Pasto), and of the extinct volcano of Sorata near Popayan. The subterranean quarries of pumice-stone near Llactagunga (635) contain much mica, oligoclase, and (which is very rare in pumice-stones and obsidian) also hornblende; the latter has, however, also been seen in the pumice of the volcano of Arequipa. Common felspar, orthoclase, is never found in pumice together with sanidine; augites are also wanting. The Somma, but not the cone of Vesuvius itself, contains pumice which encloses earthy masses of carbonate of lime. It is by the same remarkable variety of a calcareous pumice that Pompeii has been overwhelmed. (636) Obsidians are rare in true lava-currents, having been found almost exclusively in those of the Peak of Teneriffe, Lipari, and Volcano.

Passing to the association of obsidian and pumice in one and the same volcano, we find the following facts: Pichincha has large fields of pumice, and no obsidian. Chimborazo, like Etna — whose trachytes, however, have quite a different composition (they contain labradorite instead of oligoclase),—shows neither obsidian nor pumice. I also remarked their absence in ascending Tungurahua. The volcano of Puracé, near Popayan, has much obsidian intermixed in its trachytes, and has never produced pumice. Large plains, as those from which Ilinissa, Carguairazo, and the "Altar" rise, are covered with pumice. The subterranean pumice quarries near Llacta-

gunga, as well as those of Huichapa, south-east of Queretaro; the pumice accumulations at the Rio Mayo [637]; and those near Tschegem in the Caucasus [638]; and near Tollo [639] in Chili, at a distance from any active volcanic frameworks, all appear to me to belong to the class of phenomena of eruptions in the variously fissured flat surface of the earth. Another Chilian volcano, that of Antuco [640], of which Pöppig has given a description as scientifically important as it is pleasing in style, produces, like Vesuvius, "ashes," small triturated rapilli (sand), but no pumice, and no vitrified or obsidian-like rock. Without the presence of obsidian or of glassy felspar, and with great diversity of composition in the trachytes, we see both the production and the non-production of pumice. Pumice, as the sagacious Darwin has observed, is, moreover, wanting in the entire group of the Galapagos. We have already remarked elsewhere that in the great volcano of the Sandwich Islands, Mauna Loa, as well as in the volcanoes of the Eifel, which once poured forth lava [641], cones of ashes are wanting. Although the island of Java has a range of more than forty volcanoes, of which twenty-three are now active, yet Junghuhn has only been able to discover two points — at the volcano Gunung Guntur, not far from Bandong, and in the great Tengger mountains [642] — where masses of obsidian have formed. They do not appear to have occasioned any formation of pumice. The seas of sand (dasar), which are at a mean height of nearly 7000 feet above the sea, are covered, not with pumice, but with a layer of rapilli, which are described as half-vitrified obsidian-like pieces of basalt. The cone of Vesuvius, which has never emitted pumice, sent forth, from the

24th to the 28th of October 1822, sand-like ashes, triturated trachytic rapilli, forming a layer or stratum 19 inches thick, which have never been confounded with pumice.

The hollows and vesicular cavities in obsidians in which (as, for example, at the Mexican Cerro del Jacal) crystals of olivine have formed, probably from precipitated vapours, are occasionally found in both hemispheres to contain another kind of enclosures, which seem to point to the mode of their origin and formation. In the wider portions of these long-extended and mostly very regularly parallel cavities, there are morsels of half-decomposed earthy trachyte. The cavity has a narrower tail-like prolongation, as if, under the influence of volcanic heat, a gaseous elastic fluid had developed itself in the still soft mass. This phenomenon had particularly attracted the attention of Leopold von Buch in 1805, when he, Gay-Lussac, and I visited Thomson's collection of minerals at Naples. ([643]) The puffing up of obsidians by fire, which had not escaped observation in Grecian antiquity ([644]), is certainly caused by a similar development of gas. According to Abich, obsidians submitted to fusion pass so much the more easily into cellular pumice, in which the fibres are not parallel to each other, the poorer they are in silicic acid and the richer they are in alkalies. But whether the inflation is due solely to the flying off of potassa or hydrochloric acid remains, according to Rammelberg's investigations ([645]), very uncertain. Apparently similar phænomena of inflation in trachytes rich in obsidian and sanidine, in porous basalts and amygdaloids, in pitchstone, tourmaline, and the dark-brown flint which

loses colour, may have very different causes in different substances; and an examination long looked for in vain, based on appropriate and exact experiments made exclusively on the escaping gases, would lead to an inestimable enlargement of the chemical geology of volcanoes, if regard were at the same time paid to the operation of sea-water in submarine formations, and to the quantity of carburetted hydrogen in the intermixed organic substances.

The facts which I have brought together at the close of this section — the enumeration of volcanoes which produce pumice without obsidian, or much obsidian without pumice, and the remarkable, not constant, but, on the contrary, very various association of obsidian and pumice with certain other minerals — led me, long ago, during my sojourn in the Cordilleras of Quito, to the persuasion that the formation of pumice is the result of a chemical process, which may take place in trachytes of very various composition, without the necessary intervention of obsidian (*i.e.* without the necessary preceding existence of obsidian in large masses). The conditions under which such a process goes forward on a great scale are, probably, — I would here repeat, — dependent less on diversity of materials, than on degrees of heat, of pressure determined by depth, of fluidity, and on length of period of solidification. The highly noteworthy although rare phænomena presented by the isolated occurrence of vast subterranean pumice-stone quarries, apart from any "volcanic framework," lead me to entertain the conjecture (646) that a not inconsiderable portion — perhaps, according to volume, the larger portion — of volcanic rocks have been emitted, not from elevated volcanic

frameworks, but from a network of fissures on the earth's surface, from which they have poured forth, often forming, as it were, strata covering an extent of many square leagues. We are probably to include among these phænomena the old masses of trap of the lower Silurian formation of the south-west of England, by whose exact chronometric determination my illustrious friend Sir Roderick Murchison has so greatly enlarged the scope and heightened the character of our knowledge of the geological construction of the globe.

RECTIFICATIONS AND ADDITIONS.

Page 32.

A STILL much higher result for the earth's density than was obtained by Baily (1842) and by Reich (1847-1850) has been given by the pendulum experiments which Airy instituted, with exemplary precautions, in 1854, in the Harton coal-mine. The result of these experiments is to give the density 6·566, with a probable error of 0·182 (Airy, in the Phil. Trans. 1856, p. 342). A small modification of this numerical value is added by Professor Stokes, on account of the effect of the earth's rotation and ellipticity, and alters the density to 6·565 for Harton, which is in 54° 48′ N. lat., and to 6·489 for the equator.

Page 80, *line* 5.

Arago left behind him a rich mass of magnetic observations (more than 52,600 in number), obtained from 1818 to 1835, which, after a laborious redaction by M. Fédor Thoman, have been published in the "Œuvres complètes de François Arago" (tome iv. p. 498). General Sabine has discovered in these observations (for

the years 1821—1830) the most entire confirmation of the decennial magnetic declination period, and its connection with the similar period of relative paucity and frequency in the solar spots. (Arago's Meteorological Essays (Translation), London, 1855, pp. 355—357.) As early as the same year (1850) in which Schwabe, at Dessau, published his periods of the solar spots (Kosmos, Bd. iii. S. 402; Eng. p. 291), and even two years before Sabine himself first (in March 1852, Phil. Trans. for 1852, pt. 1, p. 116—121; Kosmos, Bd. iv. S. 174; Eng. note 73) connected the magnetic decennial period with that of the solar spots, he had made the important discovery that the sun appears to act by its own proper magnetic force upon the earth's magnetism. He had found (Phil. Trans. 1850, pt. 1, p. 216; Kosmos, Bd. iv. S. 132; Eng. p. 143) that the magnetic intensity is greatest, and the needle approaches most nearly to a vertical direction, when the earth is nearest to the sun. The knowledge of such a magnetic influence of the central body of our planetary system, not acting indirectly through the production of heat, but directly by its own magnetic force, as well as by variations in its photosphere (in the magnitude and frequency of funnel-shaped openings in the solar photosphere), gives to the study of terrestrial magnetism, and to the network of magnetic observatories with which (Kosmos, Bd. i. S. 346, Bd. iv. S. 72; Eng. vol. i. p. 334, present volume, p. 78) Russia and Northern Asia have been covered since the resolutions of 1829, and the colonies of Great Britain since 1840—1850, a higher cosmical interest. (Sabine, in the Proceedings of the Royal Society, vol. viii. No. 25, p. 400, and in the Phil. Trans. for 1856, p. 362.)

Page 90, *line* 4.

Although the nearness of the moon in comparison with the sun does not seem to compensate the smallness of its mass, yet the already securely ascertained variation of the magnetic declination in the course of a lunar day, "lunar-diurnal magnetic variation" (Sabine in the Report to the British Association at Liverpool, 1854, p. 11; and for Hobarton, Phil. Trans. 1857, art. i. p. 6), incites us perseveringly to continue and extend the researches on the magnetic influences of our satellite. Kreil has the great merit of having pursued this examination with great care from 1839 to 1852 (see his "Abhandlung über den Einfluss des Mondes auf die horizontale Componente der magnetischen Erdkraft," in the "Denkschriften der Wiener Akademie der Wiss. mathem. naturwiss. Classe, Bd. v. 1853, S. 45; and Phil. Trans. for 1856, art. xxii.) As M. Kreil's observations, made during several years at Milan and Prague, led him to believe that the moon causes a decennial declination period similar to that occasioned apparently by the sun-spots, General Sabine was induced to undertake a more extensive investigation, whereby he ascertained that the influence of the sun alone produces a decennial period, which indeed he had already made out for Toronto, in Canada, by the employment of a special and very accurate mode of calculation (Phil. Trans. 1856, p. 361). This influence of the sun was also distinctly manifested by the hourly observations, continued during eight years, at Hobarton in Van Diemen Island; but while, in both hemispheres, the southern as well as the northern, the

same result was found for the sun's action, they also both agreed in yielding assured evidence "that the lunar-diurnal variation corresponding to different years shows no conformity to the decennial inequality manifested in those of the solar-diurnal variation." No sufficient explanation seems yet to have been given of the lunar-diurnal magnetic variation, as General Sabine has also remarked that "the earth's inductive action reflected from the moon would seem to be too feeble to account for it." (Sabine in the Phil. Trans. for 1857, art. i. p. 7; and in the Proceedings of the Royal Society, vol. viii. No. 20, p. 404.) As the magnetic portion of this volume was printed almost three years ago, it appeared to be particularly needful, in regard to a subject to which I have been so long attached, to complete it, in some measure, by some subsequent additions.

EDITOR'S NOTES.

I.—*On the Ellipticity of the Earth.*

In the 28th and 29th pages of the German original of this volume (English translation, pp. 27 and 28), M. de Humboldt has combined the results of the pendulum experiments made by M. Biot, in conjunction with MM. Arago, Chaix, and Mathieu, at several stations of the French arc of the meridian, with those made by myself at several stations in Europe, Africa, and America, (chosen chiefly with reference to their proximity either to the equator on the one hand, or to the high latitudes of the northern hemisphere on the other,) for the purpose of drawing a conclusion upon the important question, whether the acceleration of the pendulum between the equator and the middle latitudes, and between the middle latitudes and the vicinity of the pole, indicates a uniformity, or an inequality, in the amount of the ellipticity derived from those two portions of the hemisphere. The conclusion arrived at is, that from the equator to the latitude of 45° the pendulum results indicate $\frac{1}{278}$, and from latitude 45° to the pole $\frac{1}{306}$; whilst the three series taken together give for the whole northern quadrant the ellipticity of $\frac{1}{290}$.

But before such a combination as is here made can be safely employed in the deduction of the ellipticity of the whole quadrant, and still more of separate portions of the quadrant, it is of the first importance to be assured of the strict intercomparability of results obtained in the different parts of the hemisphere by different methods and by very dissimilar apparatus.

The pendulum experiments of the French philosophers in the middle latitudes were made, as is well known, by the method and with the apparatus (slightly modified) of Borda. Mine, both in the neighbourhood of the equator and in the high latitudes, with the very different apparatus known as the Invariable Pendulum of Kater. The object which is sought by the experiment is also different in the two cases. With the apparatus of Borda, the object sought, and the result obtained, is the absolute length of the seconds pendulum at the place at which the experiment is made. The object sought, and the result obtained, by the invariable pendulum is a far more simple one, viz. the *acceleration* of the pendulum in the different latitudes to which the pendulum is successively conveyed. The acceleration is a function of the ellipticity; and the ellipticity is deduced from the acceleration, quite independently of the absolute length of the seconds pendulum at any one of the stations of experiment; which length is neither determined nor determinable by means of the invariable pendulum, nor does it need to have been determined at any station whatsoever. To bring, consequently, a series of experiments with an invariable pendulum (which furnish simply the *acceleration*, or the difference in the number of vibrations which a pendulum mecha-

nically invariable makes in a certain definite time at the different stations to which it has been successively conveyed,) into combination with another series in which the experimental object has been a different one,—viz. to determine, by Borda's method, the absolute length of the seconds pendulum at one or more stations,—requires that some *assumption* should be made, whereby the absolute lengths of the seconds pendulum at the stations where the invariable pendulum has been used may be substituted for that which is the sole and simple experimental result with the latter apparatus; and, further, that the lengths so substituted shall be such as would have been obtained by *Borda's apparatus in particular*, had it been employed at those stations instead of the invariable pendulum.

The operation of even a very small error in the requisite assumption may easily be understood when, as in the present case, the one series—viz. that of the invariable pendulum—has furnished the results in both the polar and the equatorial latitudes, and the other series—viz. that of the absolute lengths measured by Borda's apparatus—those in the middle latitudes. 1st, By the combination of the polar and equatorial results we obtain the ellipticity unaffected by the supposed error, because they form parts of one and the same experimental series, and require no substitution in lieu of the direct experimental results. They have also the very great and independent advantage of comprehending between them an arc of such extent (and consequently an acceleration of such amount), that minor errors of other kinds, whether observational, or due to local variations of the gravitating force as in-

fluenced by the disposition or density of the materials at the surface, become of comparatively minor importance. The ellipticity derived from this combination is therefore not only unaffected by the supposed error of which we are treating, but is also much less liable to be affected by errors of other kinds, than are the results of the two following combinations in which the arcs are of inferior extent. 2nd, In combining the middle latitude series with one portion—say, the equatorial—of the other series, the error of the assumption, if there be one, is involved; and though it may be a very small error, its influence on the ellipticity derived from this combination may be comparatively large, because the arc comprehended by the stations is now reduced to nearly one half of the extent it had when the polar and equatorial series were taken together. 3rd, The same reasoning holds when the middle latitude series is combined with the other portion, *i.e.* the polar portion, of the series with the invariable pendulum: but in this case the ellipticity resulting from the combination will have an error in the opposite sense to the deduction in No. 2. 4th and lastly, When the whole of the results of the two series are combined, by means of an assumption which involves a small error in the comparability of the middle latitude results with those of the polar and equatorial stations, the ellipticity resulting therefrom will exhibit a small difference from that derived from the combination of the polar and equatorial results, for the strict comparability of which no such assumption was required; but the difference will be small in comparison with that in 2 and 3, partly because opposite effects tend to counterbalance each other, and partly because

all differences are softened down by the extent of the comprehended arc.

Now the ellipticities derived from the four combinations are as follows:— 1. Polar and equatorial stations, $\frac{1}{288 \cdot 4}$; (Sabine, Pend. Ex. 1825, p. 334.) 2. Equatorial and middle latitudes, $\frac{1}{278}$; (Kosmos, B. iv. S. 28; Eng. tr. vol. iv. p. 28.) 3. Polar and middle latitudes, $\frac{1}{306}$; (Kosmos, idem.) 4. Polar and equatorial with middle latitude stations, $\frac{1}{290}$; (Kosmos, idem.) Comparing the differences thus shown with the statement that has preceded them, we may perceive that they correspond precisely to what would be occasioned by an error in some part of the process, by which a strict intercomparability has been supposed to be established, between the results obtained by myself with the invariable pendulum in the equatorial and polar latitudes, and those obtained in the middle latitudes with Borda's apparatus.

From a conviction of the great difficulty of establishing an unexceptionable intercomparability between the results of experiments in which the objects, methods, and apparatus were dissimilar, I did not hesitate, when investigating in 1825 the same question of uniformity or otherwise of the ellipticity in the two portions of the northern quadrant, to prefer the combination of Captain Kater's results at the principal stations of the British arc of the meridian with my own in the equatorial and high northern latitudes, to a combination of the experiments on the French arc with my own. In the first combination, that of Captain Kater's experiments and mine, the apparatus was the same; the method of experimenting identical; the connection between our separate series such as could

not possibly be better—we had the same base station (London), the same house in London, and the same apartment in the same house: the results at our several stations formed, in fact, one series, of unquestionable relation in every particular. For the solution of the special question which we are now considering they furnished me with three groups, remarkably well adapted for the purpose; the first comprising the five stations nearest to the equator, *i. e.* between 0° and 10° 38′ 50″ (Trinidad); the second comprising the six stations in England and Scotland; and the third group comprising the five most northern stations, *i. e.*, between 60° N. and 80° N. The ellipticity severally derived from the combinations of these three groups (which appears to have escaped the notice of M. de Humboldt) was as follows:—

Equatorial and middle latitude -	$\frac{1}{288 \cdot 3}$	Sabine,
Equatorial and high northern -	$\frac{1}{288 \cdot 4}$	Pend. Exp.
High northern and middle latitude	$\frac{1}{288 \cdot 5}$	1825, p. 346.

It is seen, therefore, that when the experiments are made under suitable and favourable conditions of uniformity in the apparatus and method, and of well assured relation to each other throughout, the supposed "anomaly" in the ellipticity of the two portions of the quadrant entirely disappears; each portion of the quadrant corresponds with the other in the amount of ellipticity which it indicates, and both correspond with the deduction made for the whole quadrant from nineteen stations distributed over its surface, extending from the equator to a few minutes short of 80° of N. latitude.

When the object of experiment is *simply* the determination of the ellipticity, the invariable pendulum unquestionably presents the most direct and the most safe method of ascertaining the acceleration in different latitudes, from which the ellipticity is an immediate deduction. It is far preferable to an independent determination, at each station of experiment, of the absolute length of the seconds pendulum, either by Borda's method, or by Kater's *convertible* pendulum; and still more to an endeavour to combine results at different stations which have been arrived at by the employment of dissimilar apparatus and processes. The determination of the *absolute* length demands a far more elaborate and delicate process of experiment than is required simply for the acceleration; and, since Bessel's remarkable discovery in 1828 (Kosmos, Bd. iv. Anm. 20), it has been known that one part of the process, whereby the absolute lengths were supposed to be determined before that date, was founded on an erroneous theoretical supposition; and hence has followed the necessity, wholly unforeseen and unsuspected by the eminent persons who devised the methods or who employed them previous to 1828, of experimentally investigating and applying corrections by no means insignificant in amount, and affecting different forms of apparatus in very different proportions.

Although it is obvious on a very slight consideration, that the corrections required by Bessel's discovery to be applied to the acceleration, derived from experiments with an invariable pendulum in which the same form of pendulum had been employed throughout, must be very small in comparison with those required for the absolute

lengths referred to in the preceding paragraph, yet, as the conclusions which have been here reproduced are taken from my publication in 1825 (which publication was anterior to 1828, the epoch of the announcement of Bessel's discovery), it may be proper on this occasion to state explicitly the degree in which those conclusions were affected by it. It is conformable to the plan of this volume of "Kosmos" (which treats of the "special results of observation in the domain of the terrestrial phænomena"), that it should contain the data upon which important conclusions are based, corrected according to the most recent emendations. Now Bessel has shown that when a pendulum moves in air the air becomes part of the moving system, and the moving force must be imparted, not only to the particles of mass of the solid body of the pendulum, but also to all the particles of mass of the air which are put in motion in accompaniment with it. The specific gravity of the moving mass, including solid and gaseous, being less than that of the solid part alone, the method employed antecedently for computing the effect of the medium in which the pendulum was vibrated, in retarding the vibration, was erroneous; and, as the quantity and distribution of the air accompanying the solid portion of the pendulum must depend upon the form and arrangement of the solid part, it followed that the true "correction for buoyancy" for each particular form of experimental pendulum required to be ascertained by special experiment. It was obvious that in the case of the determinations of absolute length, as the apparatus of Borda and that of Kater's *convertible* pendulum differed widely in form, their respective corrections for

buoyancy might be expected to differ widely from each other, as well as from the original, and now known to be erroneous, computation; and that the results would, with each apparatus, be altered by the *whole amount* of the difference between the original computation, and the true buoyancy correction as learnt by experiment; whilst in the case of the invariable pendulum the *acceleration* would only require to be corrected for a small fraction of that difference, because the greater portion would be a common error at all the stations where the same form of invariable pendulum had been used.

The kind of experiment best suited to give the true "correction for buoyancy" (or it is sometimes called "the reduction to a vacuum") for any particular form of pendulum, was sufficiently obvious, and presented no other difficulties than such as might be surmounted by a fitting apparatus, in which the pendulum itself might be vibrated alternately in air of the ordinary temperature and density, and in rarefied air approaching nearly to a vacuum.

In the same year that Bessel's discovery was announced (1828), I had such an apparatus constructed, and, by experiments recorded in the Phil. Trans. for 1829, art. xviii., ascertained that the buoyancy correction for an invariable pendulum of the form employed by Captain Kater and myself, computed by the formula which had been previously in use, required to be multiplied by the factor 1·65 in order to give the true reduction to a vacuum. The most widely differing buoyancy corrections at the 19 stations of Captain Kater and myself, computed by the original formula, were: $+ 5^s{\cdot}75$ at Sierra Leone, and $+ 6^s{\cdot}27$ at Spitzbergen, in a mean

solar day. These corrections, multiplied by 1·65, become respectively $9^s{\cdot}52$ and $10^s{\cdot}38$; or the number of vibrations in a mean solar day, computed from the results with the invariable pendulum before Bessel's discovery was made, required to be increased by ($9^s{\cdot}52 - 5^s{\cdot}75 =$) $3^s{\cdot}77$ at Sierra Leone, and ($10^s{\cdot}38 - 6^s{\cdot}27 =$) $4^s{\cdot}11$ at Spitzbergen. But the *acceleration* between these stations would only have to be corrected for the *difference* between these numbers, *i.e.* for ($4^s{\cdot}11 - 3^s{\cdot}77 =$) $0^s{\cdot}34$; and as the whole acceleration between Sierra Leone and Spitzbergen is $214^s{\cdot}8$ in a mean solar day, an error of $0^s{\cdot}34$, or about its $\frac{1}{600}$th part, would be of very small import. But it so happens that even this small error is in great part compensated by a nearly equivalent correction in an opposite sense, which is occasioned in the reduction to a uniform temperature as a consequence also of Bessel's discovery. The equivalent in seconds to 1° of Fahr. was inferred to be $0^s{\cdot}421$ in a mean solar day, from experiments made in London previously to 1828, in temperatures respectively 45°·81 and 83°·55 of Fahr. (Pend. Expts., pp. 202—207.) In this deduction the old and erroneous buoyancy formula was employed; but, on a recomputation with the old correction multiplied by 1·65, the true equivalent for 1° is found to be $0^s{\cdot}43$. (Sabine, in Phil. Trans., 1829, p. 238; and Airy, in Phil. Trans., 1856, p. 317.) Now the temperature of the pendulum during the experiments at Sierra Leone was 80°·52, and at Spitzbergen 41°·13, the difference being 39°·39, which being multiplied by ($0^s{\cdot}43 - 0^s{\cdot}421 =$) $0^s{\cdot}009$ is $0^s{\cdot}36$; by which amount the originally computed acceleration between

Sierra Leone and Spitzbergen should be *diminished* on account of the more accurate correction for the difference in the temperature of the pendulums, as it was previously shown that it ought to be *increased* by $0^{s}\cdot34$ as a more accurate correction for the reduction to a vacuum; both the more recent values of the corrections being consequences of Bessel's discovery. Sierra Leone and Spitzbergen are stations of nearly extreme difference, both in the temperature of the pendulums and in the temperature and density of the air: the effect of Bessel's discovery on the acceleration as originally computed, and, consequently, on the ellipticity originally deduced, is seen, therefore, to be wholly insignificant.

Thus it has happened that,—from my having adopted what appeared to me a more practical mode of examining the influence of differences of temperature on the time of vibration of the pendulums, viz., by causing them to vibrate at one and the same station in temperatures differing so widely as to include the whole range of temperature experienced elsewhere,—(instead of deriving the correction from the expansion of brass measured by pyrometric experiments, as previously practised),—the acceleration originally computed from my experiments in different latitudes has stood in need of little (and that little quite unimportant) correction as a consequence of Bessel's discovery in 1828. The reductions to a uniform temperature are indeed everywhere too small, if regarded as representing only the effect of the expansion of the metal on the vibrations of the pendulum; but they are experimentally all but correct when

regarded as representing the joint effects of the expansion of the metal, and of the difference of temperature on that part of the reduction to a vacuum which is not comprehended in the ancient "correction for buoyancy." (Phil. Trans., 1829, p. 238.)

Although the correctness or incorrectness of the measurements of the absolute length of the pendulum, which were made before 1828, has no bearing on the ellipticity derived, as here, from direct experiments on the acceleration, it may be well to notice the great comparative influence which Bessel's discovery has on one at least of the methods, by which the true length of the seconds pendulum was previously supposed to have been determined; whence we may at once perceive the insecurity of inferring supposed comparable values of the acceleration from absolute lengths measured in different places by different methods. Experiments made in 1830, and reported in the Phil. Trans. for 1831, art. xxv., with the vacuum apparatus already spoken of, and with the identical convertible pendulum which had been used by Captain Kater (in his experiments on the length of the seconds pendulum in London in 1817), showed that the true reduction to a vacuum of that pendulum was *more than double* the amount calculated by the formula since known to be erroneous. The true reduction was between 12 and 13 seconds in the 24 hours, instead of about 6 seconds, as computed and employed by Captain Kater; the error in his determination was consequently more than 6 seconds in a day, equivalent to ·006 parts of an inch in the length of the seconds pendulum. In the case of the *convertible* pendulum,

the amount of the true reduction to a vacuum was no doubt unusually large in consequence of its particular form, and therefore it can be no guide in regard to the similar reduction required in other experimental forms, which must in every case be ascertained by special experiment. This is one of many points which require to be investigated, before measurements of the absolute length of the seconds pendulum, by different methods and dissimilar apparatus, can be assumed with confidence as giving identical conclusions.

The variations in the rate of the pendulum at the stations of Captain Kater and myself are shown in the following tabular view. They are expressed in reference to the rate in London (86,400 seconds in a mean solar day), in the house which was the common base station of both experimentalists. The pendulum being by its mechanical construction invariable in its length (excepting only from the effects of changes of temperature), the variations in its rate are the direct results of observation at the several stations, requiring only *three* corrections to be applied:—1. for differences of temperature; 2. for differences of the density of the air; 3. for differences of elevation above the level of the sea. For the first and second, the corrections have themselves been determined experimentally; and for the third, the correction has been calculated from the duplicate proportion of the distances of the station and of the sea-level from the earth's centre, diminished by a uniform factor of 0·67. (Phil. Trans., 1819, p. 354; and Pend. Exp., p. 332.) Of the three corrections, that for the variations of temperature is the one of which the ac-

curacy may be the most open to question. The value $0^s{\cdot}43$, as the equivalent of a change of 1° of Fahr. in the temperature of the pendulum, was obtained in the experiments of 1824, by the comparison of vibrations in temperatures which differed from each other nearly the whole amount of the range of the natural temperatures experienced at the several stations, and measured by the same thermometers. But as those experiments were made in the middle of a London winter, the high temperatures were necessarily produced by heating the apartment by artificial means; and although this was done with great care, and in many respects under very favourable circumstances, it is always difficult to maintain for many hours an artificial temperature, exceeding that of the atmosphere by little less than 40°, so as to be quite sure of a correct mean temperature. For this reason I was glad to have an opportunity of examining the question afresh in 1829—1830, by experiments made at the Royal Observatory at Greenwich (with the permission of Mr. Pond, then astronomer royal,) with a pendulum similar to those I had previously employed, and with the same thermometers, in *natural* temperatures varying about 32° of Fahr. from each other. These are recorded in the Phil. Trans. for 1830, art. xix. They gave the value corresponding to 1° of Fahr. $0^s{\cdot}44$ instead of $0^s{\cdot}43$, the latter having been obtained from the comparison of the vibrations in the natural and artificial temperatures. In submitting the experiments of 1829—1830 to the Royal Society, I expressed my own preference for the value, $0^s{\cdot}44$, obtained when both the extremes were natural tempera-

tures. In restating the general results, therefore, on the present occasion, I have employed $0^s{\cdot}44$ as the equivalent of 1° Fahr. in reducing both my own and Captain Kater's results to a uniform temperature. The "reduction to a vacuum" is the ordinary buoyancy correction multiplied by the factor 1·65; and in the reduction to the sea-level the factor 0·67 has been applied uniformly at all the stations; the heights were generally small, and the reductions little more than nominal. Whatever errors in the original publication have come to my knowledge subsequently, either by my own recalculations or by information received from others, have been corrected; and three stations have been added to the original nineteen, viz. the observatories of Greenwich, Altona, and Paris, which, at the request of the council of the Royal Society, I visited subsequently to the polar and equatorial series, employing pendulums of precisely the same form and construction, and pursuing the same processes both of observation and reduction. (Phil. Trans., 1828, art. iv.; 1829, art. ix.; 1830, art. xviii.) The reductions to the sea-level have been applied to the results in the three memoirs just cited, which reductions were not required in the first instance, because the object then sought was the difference in the rate of vibration at the three observatories from the rate in London. The same coefficients have been employed in the corrections for temperature and buoyancy as at the other stations. On all occasions the invariability of the pendulums during the experiments was proved, by bringing them back to the base station, and ascertaining that their rates were unchanged.

Variations in the Rate of the Pendulum vibrating Seconds of mean solar Time in London when taken to other Latitudes :—

	Latitude.		Rate.	Observer.
	° ′ ″		s.	
St. Thomas . . .	0 24 41 N.	losing	130·68	Sabine.
Maranham . . .	2 31 34 S.	,,	140·23	Sabine.
Ascension . . .	7 55 30 S.	,,	127·96	Sabine.
Sierra Leone . .	8 29 28 N.	,,	131·67	Sabine.
Trinidad . . .	10 38 55 N.	,,	132·73	Sabine.
Bahia	12 59 21 S.	,,	126·84	Sabine.
Jamaica	17 56 7 N.	,,	114·88	Sabine.
New York . . .	40 42 43 N.	,,	42·27	Sabine.
Paris	48 50 14 N.	,,	11·48	Sabine.
Shanklin . . .	50 37 24 N.	,,	3·46	Kater.
Greenwich . . .	51 28 40 N.	gaining	0·59	Sabine.
London	51 31 8 N.	,,	0·0	Kater. Sabine.
Arbury	52 12 55 N.	,,	3·31	Kater.
Clifton	53 27 43 N.	,,	7·23	Kater.
Altona	53 32 45 N.	,,	8·94	Sabine.
Leith	55 58 41 N.	,,	17·89	Kater.
Portsoy	57 40 59 N.	,,	24·60	Kater.
Unst	60 45 28 N.	,,	35·52	Kater.
Drontheim . . .	63 25 54 N.	,,	38·77	Sabine.
Hammerfest . .	70 40 5 N.	,,	61·05	Sabine.
Greenland . . .	74 32 19 N.	,,	70·50	Sabine.
Spitzbergen . .	79 49 54 N.	,,	83·01	Sabine.

Proceeding by well-known methods, we obtain, from the data contained in the preceding table, 86263·60 as the corresponding rate of vibration at the equator, and ·0051828 as the increase of gravity from the equator to the pole; together with the ellipticity, $\frac{1}{288\cdot4}$, corresponding precisely with the value derived from the thirteen stations of my equatorial and arctic voyages. (Pend. Expts., 1825, p. 334.)

The following table exhibits the vibrations at the

several stations computed by and corresponding to these values of the equatorial rate of vibration, and of the increase of gravity from the equator to the pole; together with the vibrations actually observed at each station, and the differences, or what may be properly termed the *discrepancies*, of the observed vibrations:—

Stations.	Vibrations.		Differences.
	Computed.	Observed.	
	s.	s.	s.
Equator	86263·60		
St. Thomas . . .	86263·60	86269·32	+5·72
Maranham . . .	86264·30	86259·77	−4·23
Ascension . . .	86267·86	86273·04	+5·18
Sierra Leone . .	86268·48	86268·33	−0·15
Trinidad	86271·24	86267·27	−3·97
Bahia	86274·90	86273·16	−1·74
Jamaica	86284·80	86285·12	+0·32
New York . . .	86358·66	86357·73	−0·93
Paris	86390·20	86388·48	−1·72
Shanklin	86397·06	86396·54	−0·52
Greenwich . . .	86400·34	86400·59	+0·25
London	86400·48	86400·00	−0·48
Arbury	86403·12	86403·31	+0·19
Clifton	86407·80	86407·23	−0·57
Altona	86408·10	86408·94	+0·84
Leith	86417·02	86417·89	+0·87
Portsoy	86423·10	86424·60	+1·50
Unst	86433·64	86435·56	+1·92
Drontheim . . .	86442·24	86438·77	−3·47
Hammerfest . .	86462·42	86461·05	−1·37
Greenland . . .	86471·00	86470·50	−0·50
Spitzbergen . . .	86479·90	86483·01	+3·11

From the column of "differences" we may obtain the "probable error" of the vibrations at a single station, and the proportion in which the probable error is diminished as the number of stations is increased. Of a single station the probable error is $1^s{\cdot}7$; of 10 stations, $0^s{\cdot}55$; and of 22 stations (the number in the table),

$0^s{\cdot}36$. The equatorial rate $86263^s{\cdot}60$ consequently has a probable error of $\pm$ $0^s{\cdot}36$.

If attention be now directed to the "differences" at the ten stations between the parallels of 40° and 60° (which may be regarded as the representatives of the middle latitudes in this investigation), we do not find, either in the individual amounts, or in the systematic occurrence of either + or − signs, the indications which we should expect to find, if there were a notable discrepancy peculiar to those latitudes in the general form of the ellipticity of the hemisphere. On the contrary, the signs of opposite character are interspersed in a manner which indicates that they are of an accidental rather than of a systematic nature; and in regard to amount, the sum of the actual discrepancies at the ten stations (giving their proper value to the signs) is $0^s{\cdot}57$; whilst the "probable discrepancy" of 10 stations (computed from the discrepancies at the 22 stations,) is, as above stated, $0^s{\cdot}55$.

If we combine the equatorial vibration 86263·60 successively and separately with the vibrations observed at each of the 10 middle stations, and take the arithmetical mean of the 10 results, we obtain from these stations, so combined with the equatorial rate, ·0051828 as the increase of gravity from the equator to the pole, differing only ·0000057 from the results of the 22 stations, and corresponding to the ellipticity $\frac{1}{287{\cdot}9}$; which, viewed as a partial result derived from the middle latitudes, may be regarded as sensibly the same as $\frac{1}{283{\cdot}4}$, already stated as the general result from the equatorial and polar stations.

Having thus reasserted, and more fully justified, the

symmetrical consistency of the ellipticity of the two portions of the northern quadrant shown by the acceleration resulting from the employment of Kater's invariable pendulum, I may be permitted to rectify an accidental mistake which occurs in p. 27 of the original (p. 27 of this translation also), regarding the the origination of the experiments in which I was myself employed. The experiments of Captain Kater at the principal stations of the British Trigonometrical Survey were those which were undertaken, as stated by M. de Humboldt, at the desire of H.M. Government, pursuant to an address of the House of Commons, March 15th, 1816, which was moved by Mr. Davies Gilbert. This undertaking was completed on June 19, 1819, when Captain Kater presented the final account of his experiments to the Royal Society. The subsequent extension of the inquiry to stations including "the utmost accessible distance on the meridian of a hemisphere," originated in a proposition made by myself to the Board of Longitude, and recommended by that board (which included amongst its members several of the most eminent Fellows of the Royal Society) to the favourable consideration of H.M. Government. The object of the proposition is stated in the preface of the work in which its accomplishment is recorded, viz., "to extend the suite of stations to the equator on the one side, and to the highest accessible latitudes of the northern hemisphere on the other; to multiply the stations at both extremities of the meridian, so that, by their general combination, the irregular influences of local density (which had prevented any independent conclusion whatsoever, relatively to the figure of the earth, being drawn from the experiments

either of the French philosophers or of Captain Kater) might mutually destroy each other, and the variations of gravity due to the ellipticity alone be elicited; and to ensure the uniformity of procedure and strict comparability of the results at all the stations, by the unity of the observer and the identity of the instruments. In effect, to terminate the inquiry with the pendulum,—either by obtaining decisively the result which it might be capable of furnishing,—or by manifesting that no decisive result whatsoever was attainable by it, even under the most favourable circumstances of operation." (Pend. Expts., 1825, Preface.)

I gladly avail myself of this occasion to recall, with grateful recollection, the arrangements which existed, at that period, for facilitating the communications between Government and those who by public estimation were its most fitting counsellors, in matters appertaining to the advancement of science and to the national duty in its promotion. By means of the Board of Longitude, a proposition from an individual, known only by the desire he had shown to be employed on scientific undertakings less suited perhaps to men of higher qualifications than himself, found a ready access to Government, when sanctioned by the approval of a body in whose judgment the Government was accustomed to place confidence.

When treating of the results of pendulum experiments in the southern hemisphere (p. 28 of the German, and 28 of the English edition), M. de Humboldt has omitted to notice the experiments of Captain Henry Foster in

the years 1828—1831, which, on account of the unity of the observer, the identity of the instruments, the number of stations, and the extent of the arc which they embrace, must undoubtedly be considered to hold the first place in the determinations of that hemisphere. In January, 1828, a communication was received by the Royal Society from H.R. Highness the Duke of Clarence (afterwards King William the Fourth), then Lord High Admiral, intimating the favourable disposition of Government to extend to the southern hemisphere the investigation into the figure of the earth which had been recently completed in the northern hemisphere; and requesting from the Royal Society such suggestions as might be made the basis of the instructions to be given to the officer who might be selected to execute them. The reply was drawn up by a committee of the Royal Society, of which Sir John Herschel was chairman, and of which I was myself a member, and is preserved in the archives of the Royal Society. Captain Foster, who was appointed to conduct the experiments, had been a midshipman with Captain Basil Hall, in the "Conway," and afterwards with Captain Clavering, in the "Griper," in which ship I was then visiting Spitzbergen and Greenland, and had recently received the Copley medal of the Royal Society for his researches in several branches of physical science made during the arctic voyages of Sir Edward Parry in 1824—25 and 1827. The "Chanticleer" sloop of war having been commissioned expressly for this service, Captain Foster sailed from England in the spring of 1828, and in the course of the two following years completed the experi-

ments at the following stations, which are here ranged according to their latitudes:—

Para - - - -	1°	27′	0″	S.
Maranham - - -	2	31	35	S.
Fernando de Noronha - -	3	49	59	S.
Ascension - - -	7	55	23	S.
Porto Bello - - -	9	32	30	N.
Trinidad - - -	10	38	55	N.
St. Helena - - -	15	56	07	S.
Cape of Good Hope - -	33	54	37	S.
Monte Video - - -	34	54	26	S.
Staten Land - - -	54	46	23	S.
Cape Horn - - -	55	51	20	S.
South Shetland - - -	62	56	11	S.

To these twelve stations, of which ten are in south and two in north latitude, we must add London and Greenwich, where the pendulums were vibrated by Captain Foster before his departure from England, and the vibrations repeated (in London) by Mr. Baily after the return of the instruments at the conclusion of the voyage. Having completed the experiments at Porto Bello, the last of his pendulum stations, and whilst engaged in measuring the difference of longitude across the isthmus between Panama and Chagres, Captain Foster was accidentally drowned in the river Chagres, on the 5th of February, 1831. The papers containing his observations, arranged but not calculated, were placed by the Admiralty in the hands of Mr. Francis Baily, President of the Royal Astronomical Society, under whose directions the necessary calculations were made, and the results reported in a memoir forming the seventh volume of the Transactions of the Royal Astronomical Society.

Captain Foster was furnished with two invariable

pendulums of precisely the same form and construction as those which had been employed by Captain Kater and myself. Both pendulums were vibrated at all the stations, but from some cause which Mr. Baily was unable to explain, the observations with one of them were so discordant at South Shetland as to require their rejection. The acceleration computed from the mean of the two pendulums at all the other stations, and from the one pendulum at South Shetland, gives, according to Mr. Baily's report, pp. 74 and 75, for the increase of gravity from the equator to the pole, ·0051924, and for the ellipticity, $\frac{1}{289 \cdot 2}$. The very close agreement of this result with that which had been previously stated from the experiments in the northern hemisphere affords a very strong probability that, in the conclusion common to them both, we have a true measure of the ellipticity of the earth derived by means of the pendulum, as well as a highly interesting and important indication of symmetry in the two hemispheres.

There are two circumstances in particular which distinguish the double series of experiments discussed in this note, and may claim for their result a higher degree of confidence than has been accorded to the results of experiments made under less favourable conditions. The first is one which will be readily appreciated as soon as stated, viz., the extent of the arc of the meridian on which the stations of experiment are distributed—from 62° 46′ S. to the equator, and from the equator to 79° 50′ N. The second may perhaps be less readily appreciated at the first view; but it is a condition, nevertheless, of primary importance in results whose value is to depend on their *strict comparability* with

each other--a condition which is best secured by the employment of the same instruments and the same processes of experiment throughout. From this conviction I have limited the notice which has been here taken, both of Captain Foster's experiments and of my own, to the results obtained with the pendulums of the same form and construction as those which had been employed by Captain Kater, and with which the same methods of observation which had been first practised by him were carefully preserved. I was myself provided with two other invariable pendulums, differing in some respects in form from Captain Kater's, and attached to a train by which their vibration was maintained and the number of vibrations in a day recorded; and these were employed as a wholly distinct mode of experiment at the greater part of the stations of my equatorial and polar series. The record of the results with these pendulums is given in full in the volume of my Pend. Expts., pp. 237—287, where their close accordance is shown with those of Kater's. In like manner, Captain Foster was provided, in addition to the two Kater's pendulums, with a copper and an iron experimental pendulum (both differing in form from Kater's), which were used at several of the stations which he visited, and the results are given by Mr. Baily in the report already referred to, where they are shown to accord sufficiently for general confirmation, at the stations where they were employed, with those of Kater. It is always a great advantage to an experimentalist to be provided with a second and wholly distinct process of experiment,—though it may not be in all respects, perhaps, quite so satisfactory as the one on which he principally

relies; it inspires confidence if he finds the results accordant, and it affords the opportunity if the results should not be so, of endeavouring to clear up the discrepancy on the spot. This was the chief purpose which I contemplated in providing myself with the attached pendulums; and I found the full advantage of the provision when, at stations nearly in the same latitude with each other, and where, consequently, the rates of the pendulums should theoretically have been nearly the same, they differed to an amount of several seconds in the day, the difference being shown by all the four pendulums to nearly an identical amount; leading to the unavoidable conclusion that the discrepancy was not due to errors of observation, but was the effect of natural causes operating at the particular stations. In like manner Mr. Baily, in calculating the results of Captain Foster's experiments, appears to have derived from the same circumstance the solution of the doubts, which he is known to have entertained previously, of the true causes of such discrepancies. In the report, p. 78, he accompanies the table of comparative results by the remark that the table "clearly shows that the vibrations of a pendulum are powerfully affected, in many places, by the local attraction of the substratum on which it is swung, or by some other direct influence at present unknown to us, and the effect of which far exceeds the errors of observation. For it will be seen, from an inspection of the table, that all the pendulums tell (substantially) the same story at the same place."*

* It was at one time imagined that the angle which the plane in which the pendulum vibrated made with the astronomical or mag-

In the tabular view which is given in page 469 of the differences between the observed and computed rates, Trinidad, Ascension, and Maranham are three stations at which, in my experiments, the discrepancies were most considerable in amount:—

At Trinidad	the observed vibrations were		in defect	3·97
At Ascension	"	"	in excess	5·18
At Maranham	"	"	in defect	4·23
		Sum	-	- 13·38

For this reason it appeared to the committee of the Royal Society, by whom suggestions were made for Captain Foster's voyage, very desirable that the experiments should be repeated at those stations. This was accordingly done, and the results of the repetition are stated in Mr. Baily's report in the table, p. 88. The comparative results are as follows:— The pendulum, which vibrated seconds in London, made at Trinidad 86267·27 vibrations according to Sabine, and 86267·24 according to Foster; at Ascension, 86273·04 Sabine, and 86272·25 Foster; at Maranham, 86259·77 Sabine, and 86258·74 Foster. At Trinidad and Maranham the places of observation were identical; at Ascension there was a slight difference,—Captain Foster's pendulums were vibrated in a house in the Barrack Square, mine in a storehouse, within, I believe, a quarter of a mile's

netical meridians might influence its time of vibration. Experiment, however, had already decided this question. At Sierra Leone, the first station which I visited, the pendulums were successively vibrated in planes at right angles with each other, with results so nearly accordant as to be in effect identical. (Pend. Expts., pp. 15-16.)

distance. The sum of the discrepancies of the two observers from each other at the three stations is $1^s{\cdot}94$; the sum of the discrepancies between the *observed* and *computed* vibrations is, as above stated, $13^s{\cdot}38$. Having been myself the person who specially proposed this repetition, I may now permit myself to refer to this statement, as an additional proof that the discrepancies between the observed and computed vibrations are due, in a far greater degree, to local peculiarities, than to what may be more strictly called errors of observation. The "probable error" at a single station, calculated from the differences between the observed and computed vibrations at the 22 stations in p. 469, includes of course both station and observation errors; it is $1^s{\cdot}7$. The same computed from the differences between the two observers at the three stations above cited (regarding the arithmetical mean between the observers as in each case the true result, and half the difference between them as the error of each), is about $0^s{\cdot}3$. The latter is the probable error of observation; the former the probable error of observation and station combined; the error of observation is therefore not a quarter as large as the station error.

The differences of opinion which once prevailed regarding the causes of such discrepancies have now passed away; and they are now universally admitted, I believe, to be the effects of the unequal density of the superficial strata of the earth. They were first recognised as such by Captain Kater, in the Phil. Trans. for 1819, pp. 424—426, who drew from his own pendulum experiments at the principal stations of the British Trigonometrical Survey the conclusion that, "in passing through a country com-

posed of materials of various densities, the pendulum may be expected to indicate such variations with very considerable precision." The opinion thus expressed was considered by me to be so strikingly confirmed by the systematic character of the "anomalies" (as they were then called) at the equatorial and polar stations of my experiments in 1821-1822, as to justify the inference (Pend. Expts. 1825, p. 341,) that "the scale afforded by the pendulum for measuring the intensities of local attraction appears to be sufficiently extensive tc render it an instrument of possible utility in inquiries of a purely geological nature. The rate of a pendulum may be ascertained, by proper care, to a single tenth of a vibration per diem; whilst the variation of rate, occasioned by the geological character of two stations, has amounted, in extreme cases, to nearly ten vibrations per diem: a scale of 100 determinable parts is thus afforded, in which the local attraction dependent on the geological accidents may be estimated." The inference thus drawn was illustrated by a table (p. 338), exhibiting the general nature of the surface-strata at the thirteen stations which I had visited in 1821-1822, with the excess or defect at each station of the rate of the pendulum supposed to be occasioned thereby, and the value corresponding to the excess or defect in the scale of 100 parts; as well as by a similar table (p. 345) for nineteen stations, including those of Captain Kater. These were, I believe, the first tables of the kind that were published. It is chiefly to such local influences that we must ascribe the discordances that have appeared in the ellipticity derived from stations too few in number and too near each other in latitude. If no irregular attraction occurred, the

results computed from different portions of the meridian should be the same. By multiplying the number of stations the effects of the variations of superficial density, sometimes in excess and sometimes in defect, tend to counterbalance each other, and thus to diminish the general amount of error; whilst the increased extent of the included arc gives to such error a diminished influence on the ultimate deduction.

The discordances which were formerly found in the results of pendulum experiments, when the number of stations were comparatively few, or when the arc which they included was of small dimension, appear to have produced in M. de Humboldt's mind an impression (p. 29), that the pendulum is a less likely means of obtaining a well-assured conclusion respecting the figure of our planet than the measurement of degrees. It is not surprising, indeed, when we look back upon the formidable array of distinguished geometricians and astronomers who have taken part for more than a century past in the measurement of degrees, that there should be a bias in favour of the ultimate conclusions from a method on which such a prodigious amount of time, means, and skilled labour have been expended. Still, there have not been wanting eminent persons who have been of a different opinion; and who, viewing the discrepancies which have also presented themselves in the ellipticity deduced from different measured arcs—discrepancies arising from causes similar to those which affect pendulum results—have anticipated that the pendulum would eventually be found amongst the most accurate means of determining the general configuration of the globe. Happily, we have arrived at the time

when it is no longer necessary to discuss the claim of either of the methods to have its result accepted in preference to that of the other, since they are now found to unite in a conclusion which, if not absolutely identical, is so nearly so as to leave scarcely anything more to be desired. The calculations of the Russian arc, extending from the North Cape to the Black Sea, and the revision of the Indian arc with the comparison of its standard scale with that of the Russian arc, which are referred to in the text (p. 21) as having been in progress when that part of the volume was written, have since been completed; and although the details are not yet published, it has for some time past been known, on the authority of M. Struve, that the result of this combination is to manifest a much greater compression than had previously been deduced by Airy and Bessel in 1830, 1837, and 1841 from all the arcs then at their command. It is now known that the ellipticity derived from the Russian and Indian arcs is between $\frac{1}{291}$ and $\frac{1}{292}$; and from the magnitude of those arcs (the Russian exceeding 25°, and the Indian exceeding 21°) and the great meridional extent embraced between them, it is not likely that this conclusion will be disturbed by extensions which yet remain to be completed of arcs of less magnitude, which, being also in intermediate latitudes, are of less importance in regard to the ellipticity.

It may be worth while to cast a retrospective glance on the progressive assimilation of the ellipticity deduced from the measurement of degrees, as these measures have increased in number and magnitude and have brought into comparison more distant portions of the meridian, to the ellipticity derived from the pendulum. Without

laying undue stress on $\frac{1}{320}$, the value assigned by M. Laplace in his "Exposition du Système du Monde, 1799," we find in the second volume of Biot's "Astronomie Physique," published in 1810, $\frac{1}{308 \cdot 68}$ stated as the precise result of a careful combination of all the arcs of the meridian which had been measured up to that date. In 1830, Mr. Airy, after a careful consideration of all the arcs which had been then measured, estimated their most probable result at $\frac{1}{298 \cdot 33}$. (Encyc. Met. Figure of the Earth.) In 1837, M. Bessel, whose acquirements and habits specially qualified him for such a task, undertook the revision and rectification of the earlier arcs, and their combination with three additional arcs which had been then recently completed. The general result was $\frac{1}{299 \cdot 7}$. The extension of the Russian, and the later revision of the Indian arc, have made another step in the value of the denominator of the fraction, of nearly the same amount as the preceding step between the conclusions of M. Biot and of MM. Airy and Bessel. The difference between the ellipticity which is now found to result from the measurement of degrees, and that of the pendulum, is reduced to 3 in the denominator of the fraction which denotes the amount of the compression; or to about a fifth part only of the change which additions and rectifications in the measures of degrees have made since the early part of the century.

Viewing the obvious tendency of the two methods—the pendulum and the measurement of degrees—to unite in one and the same conclusion, we may surely permit ourselves to regard the still subsisting very small difference between them as comparatively, if not wholly, insignificant. In regard, however, to this really slight

remaining difference, I own that I am individually inclined to give the preference to the pendulum result. This preference may, no doubt, be in part owing to a natural bias in favour of what I have been myself engaged in, and, so far, be entitled to the less weight: yet it is to be remembered that the pendulum result has the advantage of nearly ten degrees of greater meridional extension than the measured arcs, and that the latter have been limited almost exclusively to the one (the northern) hemisphere, whilst pendulum experiments have been extended over both hemispheres with almost concurrent results.

In conclusion, there is one advantage which cannot be denied to the pendulum over the measurement of arcs, namely, the far less expenditure of time, means, and skilled labour which it requires. The time that intervened between the proposition to give the pendulum experiments the widest practicable extension between the equator and the pole,—and the completion of that undertaking and the publication of the results, — was barely five years. The experiments and the calculations were the work of a single person; and the conclusion from them, widely as it then differed from received opinions, has since stood as the mark towards which the subsequent results of the measurement of degrees have progressively approximated; and which, after a lapse of more than thirty years, bids fair to prove the true measure of the general figure of our planet.

II.— *On the Magnetic Disturbances.*

THE term-observations of the German Magnetic Association, superintended by MM. Gauss and Weber in 1835 and the following years, had shown that the occasional and apparently irregular disturbances of the declination magnet (to which element the German term-observations were principally confined) took place almost always contemporaneously, over the large portion of the interior of the European continent comprehended by their stations; and the numerous and rapidly varying fluctuations in the direction of the magnet which were observed to take place during a disturbance at one station, were found to occur simultaneously at other stations with an accordance admitting of no mistake. These facts, established by multiplied observations, gave a great increase to the interest with which the minor magnetic variations had been previously regarded, and caused a general desire to be felt that the investigation should be extended to more distant parts of the globe; and that, in particular, the questions of the contemporaneous occurrence of the disturbances, and the simultaneity of the fluctuations which they occasioned, should be examined over a wider field than that of the German Association, and should embrace different continents and different hemispheres.

But whilst the public attention was chiefly fixed on what were undoubtedly the most prominent and the most striking conclusions established by the extensive

system of co-operative investigation which had its head-quarters at Göttingen, there were others also which, although they attracted less notice at the time, were not less apparent upon a close examination of the simultaneous observations at distant stations. By a careful examination of the diagrams in which these were represented in the *Resultate aus den Beob. des magnetischen Vereins*, it could not fail to be perceived that (after due allowance was made for the small differences at the several stations of the absolute horizontal force of the earth, which is the antagonistic of the disturbances), the disturbing causes, whilst acting simultaneously, produced more extensive deflections at certain stations than at others, indicating thereby that the energy of the disturbing force itself was subject to variations due to unknown peculiarities. Examples were not infrequent also, in comparing the movements of the declination magnet at two stations, of a difference in the proportional magnitude of successive deflections, one deflection being greatest at the one station, and another deflection greatest at the other station. Though almost always exhibiting the same feature of simultaneity, the deflections showed considerable variety, and apparent irregularity, in their extent. The conclusion seemed almost unavoidable, and appears accordingly to have been entertained by M. Gauss himself, that more disturbing forces than one were contemporaneously in action; that these were, possibly, quite independent of each other, and might have very different sources; their effects being intermixed in very dissimilar proportions at places differently situated in relation to the position and distance of their respective sources. The disentanglement

of the complications produced by this presumed superposition of phenomena,—the separation of the individual forces of which the fluctuations are the compound result,—and the assignment of the source and measure of each,—were viewed by that eminent geometrician as "triumphs of science" which, though "incontestably very difficult of accomplishment," might not be unattainable by perseverance in the course of inductive investigation which had been so happily commenced. (Resultate, 1836, pp. 99—100.)

The scheme of the British colonial observatories, adopted by the British Government on the joint recommendation of the Royal Society and of the British Association for the advancement of science, was much more comprehensive than that of the German Association, inasmuch as it included the investigation of the laws of all the magnetic variations, secular, periodical, and occasional, sensible at the surface of the globe; and embraced as distinct subjects of inquiry the phenomena of each of the three magnetic elements, the declination, the inclination, and the intensity of the magnetic force, — the whole phenomena, in fact, of the magnetic direction and force, as they might be severally affected by the different variations. The occasional disturbances (the subject of this note) still preserved, however, a prominency in the order in which the investigations were to be made; from the circumstance, that the progressive and periodical variations appeared to be so mixed up with the influences of the transient and occasional, that a knowledge of the laws and relations of the latter, whereby their effects might be eliminated, was deemed to be indispensable towards a correct investigation and analysis

of the former. The study of the occasional disturbances was therefore taken up at the point to which it had been carried by the German Association. The questions,—of general contemporaneous occurrence,—and of the degree of simultaneity and accordance in individual fluctuations of the disturbed magnets,—were examined at observatories established in Africa and America, as well as in Europe, in the northern and southern hemispheres, and in the tropics, by observations of the three elements at short intervals, at preconcerted instants of absolute time, as well as generally on all occasions when fluctuations of more than usual amount presented themselves in the course of the regular hourly registration. The result of this examination was conclusive in reference to the contemporaneous occurrence of the phenomena in all parts of the globe. Not only were the same days characterised in the records of the different observatories as being "days of unusual disturbance," but even the degree assigned to the disturbance, as "excessive," "great," or "moderate," was usually the same at stations most distant from each other. The instants of extreme disturbance in one of the elements in one part of the globe were frequently as nearly identical as the nature of the observation permitted, with those of the same or another element in a very distant part; and the culminating points of minor fluctuations as frequently exhibited a degree of accordance characteristic of the existence of *general affections*, extending simultaneously over the whole surface of the globe, but influencing the magnetic elements *variously*, according, possibly, to the geographical position of the station, or to its distance and direction from the locali-

ties which may eventually be found to be those of the sources of disturbance. The correspondence which had been manifested in the fluctuations of the declination in Europe was also found to prevail in much the same degree when the term-day curves at different stations in Canada and the United States were compared *inter se;* but in a far less degree when the simultaneous curves of the two continents were placed in comparison. Indications indeed were not wanting of the participation of both continents in disturbances having a common origin; but additional and still stronger evidence, of dissimilarity in the particular effects produced by the disturbing action in different localities, gave weight to the earlier inference of an *admixture of forces*, acting simultaneously and occasioning complication, for the disentanglement of which some new process of investigation appeared to be required. Now it was obvious that if more forces than one were in general action at the same time, a properly directed analysis of the disturbances *at a single station* might separate their effects, and exhibit their respective laws more simply and readily, than when additional complexity was introduced by having to consider at the same time the different action of the same forces at different places. In such an inquiry the first questions which would present themselves for solution would be, whether any *periodical* influence were discoverable in the *mean effects* of phenomena which were themselves of occasional, and in a certain sense, irregular occurrence; and if so, whether the different magnetic elements had the same or different periodic laws; and whether, in each element taken separately, the fluctuations which were observed to take

place on opposite sides of the mean or normal values had the same or different periodic laws. For this investigation, the hourly observations, which had been maintained with steady perseverance for several years at the British Colonial Observatories, appeared likely to furnish a suitable provision, if a selection were made from them of a sufficient body of the particular class of phenomena to enable their laws to be studied. As the magnitude of deflection was the only known criterion of a disturbance of the class which had been termed "irregular," a number of the largest deflections (reckoned from the mean or normal values in the same month and at the same hour) were separated from the whole body of the observations for the proposed examination. Care was taken that the amount of deflection, which should cause an observation to be regarded as "disturbed," should be on the one hand so low as to separate a sufficient number of disturbed observations for the deduction of mean effects, whilst, on the other hand, it should be so high as not to include irregularities of the ordinary regular and well-known variations: and that the same disturbance-value should be taken throughout, in order to insure a just comparison between different months and different years. The observations so separated were formed into tables both of the numbers and of the aggregate values of the deflections (reckoned from the normals) according to the years, months, and hours, of their occurrence; and the *mean* annual, monthly, and daily numbers, and aggregate values, being severally taken as units, the relative proportions of frequency and of amount of disturbance, in the several years, months, and hours, were obtained. The aggregate

amounts of deflection were also divided into "deflections on either side of the normal," and treated in the same way. The variation in *relative* frequency and amount in the respective periods being the object of this investigation, the *absolute* numbers and values of the separated observations would have no other importance than as evidencing that they were sufficiently large to justify the deduction of the *relative* proportions. The numbers and values would, of course, be larger or smaller according as the amount of deflection taken as the measure of a disturbed observation were lower or higher; but it was soon found on trial, that there were always certain moderate limits within which this amount might be taken indifferently without producing any material alteration in the relative proportions. At stations where the energy of the disturbing force was great in comparison with the deflections produced by the ordinary and regular variations, a larger body of disturbed observations could be safely separated: but in no case could the separated values be regarded as furnishing a measure of the whole effects of the occasional disturbances; inasmuch as, until some other criterion than that of magnitude is known, by which an effect of the particular causes now under notice can be discriminated, there must always be supposed to be minor effects of the same causes remaining amongst the unseparated body.

By pursuing this method of investigation with the observations that had been received from the observatories of Toronto, St. Helena, and Hobarton (stations widely distant from each other on the globe), the same conclusions were obtained from each, viz. that the disturbances are governed, in the frequency of their occurrence,

and in the magnitude of their mean effects, by several periodical laws of a highly systematic character, admitting of well-assured determination. Perhaps the most important of these periodical laws is the one which has been honoured by M. de Humboldt's notice more than once in the present volume, because its discovery first established the connection of the terrestrial magnetic variations with the periodical variations in frequency and amount of the *solar spots*, thus affording a more certain evidence than any which had preceded it, of a direct magnetic influence emanating from the central body of our system, and producing phenomena at the surface of our planet, in the production of which it was scarcely possible to imagine that the solar magnetic influence acted through the instrumentality of variations of temperature. The *decennial* period, as it has been termed (though some uncertainty still prevails as to its precise length), is apparently a *solar* period, inasmuch as we perceive it to form a recurring cycle in the physical appearance of the solar disk, whilst on our earth it has no other physical manifestation or accompaniment than those magnetic variations, which in other ways also (as in their annual and diurnal periods) manifest their dependence upon the sun. The epoch of greatest obscuration in the solar disk by the dark spots, is characterised on our globe by a maximum prevalence of the magnetic disturbances, by their greater frequency, duration, and occasional magnitude, and consequently by the greater amount of their aggregate effects; whilst the epoch of minimum in the solar obscuration is analogously characterised by a corresponding minimum in the magnetic affections. The decennial period is shown

separately by each of the three magnetic elements, and has been evidenced alike wherever observations have been maintained for a sufficient time to include the two opposite epochs of the period, and have been submitted to a suitable process of examination.

The primary connection of the disturbances with the sun is evidenced also by the discovery, (which has been another result of the mode of investigation referred to), that their *mean effects*, in all parts of the globe and in each of the elements, are found to be invariably governed by periodical laws, whose period is a *mean solar day.* This is the one feature which is constant, amidst diversities in the hours of maximum and minimum of the different elements at the same station, and of the same element at different stations,— diversities which fully account for the absence of absolute correspondence in the simultaneous movements of the magnetometers at places distant from each other, and harmonise with the conjecture of the contemporaneous existence of more than a single force. It is in this view especially to be noticed that, at the same station, the disturbances which produce easterly deflections of the declination, and those which produce westerly deflections of the same, have distinctly different laws; as have also the disturbances which increase and those which decrease the inclination, as well as those which increase and those which decrease the intensity of the magnetic force. The laws are in all these cases highly systematic, the hours of maximum and minimum well marked, and the progression regular. There are thus, at each station, six distinct phenomenal laws of this particular class of phenomena coexisting, and necessarily producing much complexity by their

combination; and when to this complexity at one station is superadded the additional complication of the diversity of the action of the same forces at different stations, an amount of intricacy is produced, which has caused the earlier method of investigation, by the comparison of term-day observations, to yield latterly so little fruit in proportion to the labour which has been bestowed in the accumulation of materials. By the substituted method, and by taking the stations separately, the intricacies are unravelled; and each of the six laws is found to admit of separate determination. Although the three stations already named, at which this has been accomplished, are too few and too far between to furnish an adequate basis for generalisation, yet, the measure of success already obtained gives us full reason to believe, that by perseverance in the path which has been opened, we have a fair prospect of discerning the mutual relations which cannot fail to belong to forces having the same origin, as well as of distinguishing more clearly than we are at present able to do between forces which have distinct sources; and thus of completing the "triumph of science" which was anticipated by the great geometrician.

Already the very recent addition of the disturbance laws of but a single element (the declination) at a new station, Point Barrow (Phil. Trans., 1857, art. xxiv.), has made known a mutual relation, of a most remarkable and suggestive character, existing between the phenomena at Toronto and Point Barrow,—the laws of the easterly deflection at the one station being found to correspond at the same local solar hours with those of the westerly deflections at the other station, and *vice*

versâ. (There is about six hours' difference in the absolute time corresponding to the same solar hours at the two stations.) The great disproportion also in the magnitude of the disturbances at Toronto and Point Barrow is most conclusive evidence of the greater energy of the disturbing forces at some parts of the globe than at others; and leads to the natural inference that at Point Barrow we are in close proximity to one of the sources from which their actions emanate.

The extraordinary manifestation of concomitant auroral phenomena, and the insight which we have gained thereby into the horary laws of their occurrence, and into the relation of these laws to those of one in particular of the disturbance variations, unite in indicating the neighbourhood of Point Barrow as one of the most important localities on the globe for the further prosecution of these researches.

III.—*On the solar-diurnal variation of the Magnetic Declination.*

UNDER the ordinary name of "diurnal variation" are usually included several independent variations, distinguishable apart by their respective hours of maxima and minima, and by the characters of their progressions, but which unite in one common feature and are thereby traceable to one common primary cause; the common feature being that, in all, the period of variation is a mean solar day. Our first knowledge of these variations is obtained by observing them in their conjoint or accumulated effects, viz. in the changes of direction which they produce in a freely suspended magnet at the different hours of the day and night. It is the business of the analyst, by various modes of grouping and combining the observations, to distinguish from each other the effects which proceed from different sources, and as the first step towards a knowledge of the physical causation by which such dissimilar effects are made to proceed from the same primary source, to ascertain their several phenomenal laws. The investigation which has this purpose in view has already made some progress; and its advance may perhaps be aided by an endeavour to classify the natural facts of which a knowledge has thus been acquired. The endeavour must necessarily be imperfect, because our knowledge is still but partial and incomplete, as well as of very recent acquisition; and because we have as yet no true theoretical perception

of the agency by which any of the natural effects are produced. It may tend also to a better appreciation of the difficulties to be overcome, in obtaining a *scientific* knowledge of the phenomena which present themselves to the magnetic observer at the first outset, (viz. the changes which he perceives to take place in the compass-needle in the course of a single day), that it should be shown what a variety of effects are combined in those changes sometimes thought to be so simple. We may commence the classification by describing the principal characteristic features of the *mean* diurnal variation; or the result we obtain when we take an average of the diurnal variation observed on every day of the year, and thereby eliminate for the moment any systematic differences which may belong to different portions of the year.

§ 1. *Mean diurnal variation.*

When proper precautions are taken to protect a declinometer from casual and non-magnetic disturbances, and when *means* are taken for every hour of all the observations made at that hour throughout the year, it is found that there are certain stations on the globe where these means show scarcely any notable difference in the direction of the magnet at any hour of the day or night. In conformity with the terms frequently employed of "north and south magnetic hemispheres," such stations may be magnetically termed "equatorial stations." In receding from them, either to the north or to the south, indications begin to appear of a systematic horary difference, *i. e.* a diurnal variation, in the declination, and

these progressively augment in arc-value, until in the middle latitudes of both magnetic hemispheres the extent of the variation, or the difference between the extreme easterly and westerly values in the course of twenty-four hours amounts, on the annual mean, to nine or ten minutes. The deflections, or departures from the mean declination are greatest during the hours of the day; a circumstance which does not require, however, the actual presence of the sun above the horizon, as it takes place also in the arctic circle during the polar winter. The extreme deflections occur, in the middle latitudes of both hemispheres and in all meridians, at nearly similar hours of solar time; but with the characteristic distinction, that, (speaking always of the north end of the magnet,) in the northern hemisphere the extreme easterly deflection takes place in the forenoon, and the extreme westerly in the afternoon; and conversely, in the southern hemisphere, the extreme westerly deflection in the forenoon and the extreme easterly in the afternoon. The hours of the extremes are, for the forenoon, from 7 to 10 A.M., and for the afternoon from 1 to 3 P.M.: the change of direction is most rapid from 10 to 11 A.M. The hours of extreme deflection, or, as they are frequently called, the "turning hours," do not appear to depend, as some physicists have supposed, on the angle which the magnetic direction may make with the astronomical meridian (viz. on the declination); as the hours are approximately the same in places which differ very widely from each other in that respect. For example, at Dublin, where the declination is 29° west; at Prague, where it is 17° west; at Toronto, where it is

2° west; and at Point Barrow, where it is 41° east;—at all these places the westerly extreme takes place within a few minutes of 1 P.M., and the easterly extreme between 7 and 8 A.M., although the extreme difference in the declination is 70°, which is equivalent to a difference of between four and five hours in the magnetic azimuth of the sun at 1 P.M. From the great distances apart of these four stations it may not be unreasonable to infer, that the turning hours in which they all agree may be found to be approximately the same, (apart from the effects of the occasional disturbances), throughout the middle latitudes of the northern hemisphere. When we examine the corresponding phenomena of the southern hemisphere, however, we find a remarkable difference in the turning hours of the middle latitudes, which (though not inconsistent with what is stated in the earlier part of this note, viz. that the hours in both hemispheres are *nearly* similar) seems to indicate a *systematic hemispherical difference* of fully an hour and a half in the times of occurrence both of the forenoon and afternoon extremes. Hobarton is the station, in the southern hemisphere, where the hours of extreme deflection have been most securely ascertained, on the extensive basis of eight years of hourly observations. These have given between 9 and 10 A.M. for the time of the forenoon extreme, and between 2 and 3 P.M. for that of the afternoon extreme. The turning hours observed by Sir James Ross in his Antarctic Expedition, at the Auckland Islands, at New Zealand, and at Sydney are in accordance with those at Hobarton. Although the hourly observations at Sir James Ross's three stations were continued but for a few weeks at each, the results

which they have thus yielded are most valuable when taken in conjunction with the conclusions from the Hobarton observations; which if they had stood alone might have been deemed indicative of local peculiarity, rather than as affording a distinct hemispherical type. In the present state of our knowledge, or rather in our present deficiency of knowledge, no physical explanation of such a systematic difference of the turning hours in the two hemispheres readily presents itself; and we must therefore consider it as particularly desirable that further investigation should be made of the corresponding phenomena in other parts of the middle latitudes of the southern magnetic hemisphere.

Besides the deflections which occur during the hours of the day there are others, though of much minor extent, which occur during the hours of the night. There is reason to believe that these are in great measure if not altogether produced by the occasional disturbances; which, as stated in the preceding note, are now known to be governed in their mean effects by periodical laws, amongst which is one which has for its period a solar day, and has different hours of maximum and minimum from those which have been described as belonging to the regular diurnal variation. But these effects, as well as peculiarities which have been occasionally found in the diurnal variation observed in the higher latitudes of the northern hemisphere, and which there is reason to believe are also traceable to the effects of the occasional disturbances in the regions where those effects are the most largely developed, will be more advantageously treated of in a subsequent section.

§ 2. *The semi-annual inequality.*

The diurnal variation described in the preceding section is that which we find when we take an average of the whole year, and corresponds with what we may suppose would actually take place throughout the year if the sun's path were always in the plane of the equator. But observation has made known to us the existence of a semi-annual inequality in the diurnal variation, having opposite phases according as the sun has north or south declination; having consequently its turning epochs about the times of the solstices, and disappearing, as one phase passes into the other, about the times of the equinoxes. As far as can be judged from the stations where the facts have been most satisfactorily examined, which are chiefly equatorial and middle latitude stations, the semi-annual inequality is a general phenomenon, and nearly uniform in character and amount at all stations. Its principal effect takes place during the hours of the day, the extreme deflections occurring about 7 or 8 A.M., and from 1 to 2 P.M.; the north end of the magnet being deflected in the forenoon to the east when the sun is north of the equinoctial, and to the west when he is south of it; and, conversely, in the afternoon to the west when the sun is north, and to the east when he is south of the equinoctial. In other words its effect is,—when the sun has north declination to cause the north end of the magnet in both hemispheres to be more to the east in the forenoon, and more to the west in the afternoon, than it would otherwise be,—and

when the sun has south declination to cause the north end of the magnet in both hemispheres to be more to the west in the forenoon, and more to the east in the afternoon, than it would otherwise be. The range of deflection from one solstice to the other is about 3′ or 4′ at the extreme or turning hours; and the daily range from the forenoon to the afternoon is throughout the year also about 3′ or 4′, except about the equinoxes when the opposite phases pass into each other. The transition from the one phase to the other takes place rapidly, and is nearly completed a few days after each of the equinoxes.

We may now consider the general effect of the superposition of the semi-annual inequality upon the *mean* diurnal variation stated in the preceding section. In the middle latitudes of the northern (magnetic) hemisphere, the eastern extreme of the mean diurnal variation has been described as being reached about 7 or 8 A.M., and the western extreme about 1 or 2 P.M.; the mean range during the year being about 9′ or 10′: whilst in the middle latitudes of the southern (magnetic) hemisphere, the contrary extremes are attained nearly at the same hours; and the mean range is the same, or nearly so. Now, as the range of the semi-annual inequality is less than 9′ or 10′, its superposition upon the mean diurnal variation in the middle latitudes in either hemisphere does not alter the *character* of the forenoon or afternoon extremes in any part of the year, but it does alter their *amount*. During the greater part of the half year in which the sun has north declination, the semi-annual inequality

described in this section has the effect in the northern hemisphere of increasing both the forenoon easterly and the afternoon westerly deflections, and in the southern hemisphere of decreasing both the forenoon westerly and the afternoon easterly deflections—and during the greater part of the other half year in which the sun has south declination, the semi-annual inequality has the opposite effects, *i.e.* in the northern hemisphere, it decreases both the morning easterly and the afternoon westerly deflections, and in the southern hemisphere, it increases both the morning westerly and the afternoon easterly deflections. The apparent complexity of the phenomena which we have described is occasioned by the remarkable difference which takes place in the mode in which the sun's influence is exercised in producing, 1. the mean diurnal variation, and 2. the semi-annual inequality of the same. In the first the directions of the deflection are uniform throughout the year in the middle latitudes of the one hemisphere, and (although opposite) are also uniform throughout the year in the middle latitudes of the other hemisphere; whilst in the semi-annual inequality the directions of the deflection are uniform in the two hemispheres, but opposite in the two half years. Thus in each hemisphere the semi-annual deflections concur with those of the mean diurnal variation for half the year, and consequently augment them; and oppose, and consequently diminish them in the other half year.

We have next to consider the effect of the superposition of the semi-annual inequality at the magnetic equator and adjacent stations, using the term "mag-

netic equator" in this case to denote a line passing round the globe, and dividing it into two hemispheres which are distinguished apart by the *mean* diurnal variation having opposite deflections at the same hours throughout the year. On the dividing line there is no *mean* diurnal variation; but it is by no means a line without diurnal variation, for in each half year the alternate phases of the semi-annual inequality constitute a diurnal variation of which the range in each day is about 4 minutes, and which takes place every day in the year except about the equinoxes; the march of the diurnal variation being from east in the forenoon to west in the afternoon when the sun has north declination, and from west in the forenoon to east in the afternoon when he has south declination. As the magnetic equator is receded from on either side towards the middle latitudes, the *mean* diurnal variation characteristic of the hemisphere becomes more and more sensible, producing, with the deflections of the semi-annual inequality, compound phenomena, in which the character of the semi-annual inequality, (consisting of opposite deflections at the same hours in opposite parts of the year,) is preserved, until the amount of deflection at the turning hours of the *mean* diurnal variation preponderates over that of the semi-annual inequality: when the phenomena pass from the character of *equatorial* to that of *middle latitude* stations. St. Helena is an example of the equatorial phenomena; Toronto of the phenomena described as being those of the middle latitudes of the northern hemisphere; and Hobarton of those of the middle latitudes of the southern hemisphere.

The description which has been given of the pheno-

mena of the semi-annual inequality is in no way inconsistent with the ingenious hypothesis suggested by the late Dr. Langberg for its explanation (Proc. Royal Society, vol. vii. p. 434). The epoch of the transition from the one semi-annual phase to the other certainly takes place *about* the time of the equinoxes, but it cannot be said that observation has yet defined the precise day of the transition at either equinox.

The important question next presents itself, by what other geographical or magnetical peculiarities is the line distinguished, which we may regard as the zero-line of the mean diurnal variation, and where consequently the semi-annual inequality constitutes the sole subsisting diurnal variation? The places which first made known to us these characteristic phenomena of a magnetically-equatorial station were St. Helena and the Cape of Good Hope. Both are situated near the line of least magnetic force on the surface of the globe. This is a line encircling the globe, passing through and connecting the points in each terrestrial meridian where the magnetic force is least in that meridian: it is not therefore itself an isodynamic line, but divides the surface of the globe into two hemispheres, in each of which the magnetic force progressively increases on either side of the dividing line, until the isodynamics form lemniscates around the two foci of maximum force in each hemisphere. In this respect it has a claim to be considered as a magnetic equator; and its claim will be greatly strengthened if it be identified, as seems probable, with the zero-line of the sun's mean diurnal influence on the globe. It would be superfluous to dwell on the obvious theoretical importance of

establishing decisively, by observations at a sufficient number of well-selected localities, whether this line of least force, or some other line which according to various hypotheses might be deemed to have a preference, be really the zero line of the mean diurnal variation; viz. the line in which, apart from the semi-annual effect produced according as the sun has north or south declination, the diurnal variation disappears, and in which the semi-annual effect also disappears about the times of the equinoxes,—but only then. Those who incline to ascribe all the minor magnetic variations, and prominently amongst them the diurnal variation, to thermic agency, or to thermo-electric currents generated on the surface of the globe or in the higher regions of the atmosphere, might, according to distinctions in their particular views, be disposed to prefer either the terrestrial equator, or some variable line, such as "the parallel of latitude which has the sun in its zenith," as the most probable line from which effects should commence, which are supposed to proceed from the more heated to the less heated portions of the globe. Amongst those who, on the other hand, might deem it more probable that effects which are in themselves *magnetic*, might have a reference in their distinguishing phenomena to characteristic lines of the earth's magnetism, there would doubtless be many who would be disposed to give a preference to the line of no dip, so frequently termed the magnetic equator. In such important questions we naturally desire indisputable evidence; but this we scarcely as yet possess, though the facts already known appear to point most distinctly to the line of least force as meriting a decided preference.

The station, St. Helena, which first placed in a clear and unmistakable point of view the peculiar features of the semi-annual inequality, and the at least approximate absence of any other diurnal variation, is in 15° 56′ south latitude, and has a magnetic dip of 22°. The distance, therefore, is considerable, both from the terrestrial equator and from the line of no dip; and in respect to the sun's verticality, he is in the zenith of St. Helena in the first week of November and the first week of February, whereas the *equinoxes* are the epochs when the opposite phases of the semi-annual inequality pass into each other, and all diurnal variation disappears. On the other hand, St. Helena is situated in the close vicinity of the present position of the line of least force, which, in consequence of the great distance apart (in that quarter of the globe) of the two foci of maximum force in the southern hemisphere, has a large southerly inflection, and passes between St. Helena and the Cape of Good Hope, but somewhat nearer to St. Helena. The Cape of Good Hope furnishes still stronger evidence to the same effect: the phenomena are similar, indeed nearly identical with those at St. Helena, marking the Cape distinctly as a magnetically-equatorial station, whilst its geographical latitude is 33° 56′, and its dip 53° (*very* distant therefore from the line of no dip), and the sun is not vertical in any part of the year. A very instructive contrast is presented when we compare the diurnal variation at Algiers and at the Cape of Good Hope; the two stations are at opposite points of the same continent, Algiers in 36° north, and the Cape in 34° south latitude, and are therefore nearly equidistant from the terrestrial equator: and as the dip is 57° north

at Algiers, and 53° south at the Cape, they are also both very distant (and nearly equidistant) from the line of no dip. But while their situation is thus nearly symmetrical in regard to distance from the equator and from the line of no dip, it is much otherwise in respect to the line of least force, which enters the African continent only a little to the north of the Cape of Good Hope, and at a very much greater distance from Algiers. Now, at the Cape, the semi-annual inversion of the hours of extreme easterly and extreme westerly elongation is a very decided feature, scarcely less so than at St. Helena. When the sun has south declination, the extreme westerly elongation is in the forenoon, and the extreme easterly in the afternoon; and when the sun has north declination, the converse takes place both in the forenoon and afternoon. The Cape thus possesses this peculiar character of a magnetically equatorial station. At Algiers, on the other hand, the extreme easterly elongation is, throughout the year, in the forenoon, and the extreme westerly in the afternoon. (Aimé: Explor. Sci. de l'Algérie, 1846, t. ii. p. 218.) Algiers has not, therefore, this character of a magnetically equatorial station; whilst the Cape has it. Again, at the Cape, when the semi-annual inequality is eliminated, (by taking a mean of the two half-years so that their opposite deflections may counteract each other,) the residual, or mean diurnal variation is extremely small, and is such as corresponds to a station very little removed from the line where it would vanish altogether; whilst at Algiers, the mean diurnal variation has a range of about 7′·5 (Aimé, p. 19), which is little less than at Toronto or Hobarton. Thus, in this respect also, Algiers has the

character of a middle latitude station, and the Cape, that of an equatorial station.

The facts thus cited seem to be quite irreconcilable to the thermic or thermo-electric-current hypotheses; and not less so to M. Arago's belief that the diurnal variation would be found to have changed completely "du moment où le soleil a passé d'un côté du zenith à l'autre:" nor do they sanction the opinion that the line of no dip should be regarded as the magnetic equator.

It seems to follow from what has been said, that a physical explanation of the facts of the semi-annual inequality will have to account for the epochs at which the half-yearly phases pass into each other, which epochs appear to respect the sun's passage of the *geographical* equator,—and also for the terrestrial distribution of the phenomena in question, which appears to respect the *magnetical* equator, or the line of least magnetic force.

It has been stated above, that the turning hours, or hours of greatest easterly and greatest westerly deflection of the semi-annual portion of the diurnal variation, are from 7 to 9 A.M., and from noon to 2 P.M. On pursuing this correct general statement into still more precise details, we find, within the above-named limits, a remarkable difference between the two *half-years*, strikingly analogous to a similar difference pointed out in the preceding section, as existing between the exact turning hours of the regular solar-diurnal variation in the two *hemispheres*. When the sun is in the northern signs, and the direction of the movement pertaining to the semi-annual inequality agrees with that of the regular solar-diurnal movement throughout the year in

the northern magnetic hemisphere, the times of the semi-annual inequality movement are systematically earlier than in the opposite half-year, when the sun is in the southern signs, and when the direction agrees with that of the regular solar-diurnal movement of the southern hemisphere: just as the times of the regular solar-diurnal movement are throughout the year earlier in the northern than in the southern hemisphere. In this minor detail, as well as in the broader features, we have similar semi-annual and hemispherical agreements and differences. The distinctive character of the two half-years is seen in its simplest form at magnetically-equatorial stations, where the regular solar-diurnal variation drops out altogether, and the semi-annual inequality constitutes the sole diurnal variation (during the hours of the day). It is well shown (in the forenoon extremes particularly) in the Phil. Trans. 1847, Art. VI. Plates 3 and 4, where the analogy with the hemispherical difference of the regular solar-diurnal variation is also pointed out. It seems, as far as can be yet judged, to be a general and systematic natural feature, and one too important to be safely overlooked by those who are seeking for physical explanations of the minor magnetic variations.

§ 3.—*Diurnal Variation caused by the Disturbances.*

It has been stated in Note II., that amongst the periodical laws by which the mean effects of the disturbances are governed, there is one which has for its period a mean solar day. We have still, therefore, to consider

the additional complication which is occasioned by the superposition of this disturbance-diurnal variation upon the variations treated of in § 1 and § 2. Respecting the disturbance-variation generally, it must be noticed in the first place that, although it presents at each of the stations where it has yet been examined, the same characteristics of a regular, systematic, and easily determinable progression, with well-marked hours of maxima and minima, these hours, unlike the turning hours of the variations treated of in the two preceding sections, vary at different stations apparently without limit. It had been at one time inferred from observations at a European station, "that the disturbance-variation has always the same direction as the regular solar-diurnal variation, and thus the disturbing forces tend only to increase the action of the forces which produce the solar-diurnal variation;" this conclusion, perfectly well-founded as regards the evidence derivable from one station, may be met with equal truth by an exactly opposite one at another station. For example, at two places on the American continent, Toronto and Point Barrow, the regular solar-diurnal variation has the same turning hours, and the same direction at both stations. But the disturbance-variation turns, indeed, at both stations, nearly at the same hours, but does so in opposite directions, the greatest westerly extreme of the disturbance-variation at the one station being reached nearly at the same hour as the greatest easterly at the other station, and *vice versâ;* so that at one station the two variations (as in the European case above referred to), agree with and reinforce each other; while at the other station they oppose, and, to a certain extent, counteract

each other. There seems reason to believe that the general characters of the regular solar-diurnal variation, in regard to the hours of its easterly and westerly extremes, are the same in all the extra-tropical portions of the same magnetic hemisphere; whilst in the case of the disturbance-variation, it seems probable that every diversity in the times of occurrence of the turning-hours may be found in different localities. The stations at which these laws have been elicited are not yet sufficiently numerous and varied to afford sufficient indication of the mutual connections, or of the geographical or magnetical relations, which may possibly hereafter be traced and throw additional light on the nature of the causes concerned. The easterly and westerly disturbance-deflections at the same station have also distinct laws of diurnal variation, which appear to have no necessary or determinate relation to each other, and are only to be learnt, like their conjoint effects, by examination. The determination of these effects with a view to their elimination, is a first step towards a *true presentation of the phenomena of the regular diurnal-variation,* inasmuch as prior to such determination we cannot anticipate, with any degree of certainty, at what hour of the twenty-four either the easterly or the westerly extreme disturbance-deflection may be found: nor, in reference to the comparative magnitude of the disturbance-variation and the variation from other sources upon which it is superposed, can we with confidence affirm more than that the disturbance-variation may be expected to be smallest at magnetically equatorial stations,—quite sufficiently large in the middle latitudes to exercise frequently a very perplexing influence on results from

which it has not been eliminated,—and in still higher latitudes (more particularly when we approach the localities from whence the disturbances appear to emanate), so great as to mask altogether the diurnal variation proceeding from other sources.

It has been stated that the principal deflections caused by the diurnal variation in the course of the twenty-four hours, are those which take place during the hours of the day. We have now to consider the minor phenomena that occur during the hours of the night. The progressive march of the declination-magnet from the extreme elongation which it reaches in the early hours of the afternoon to its opposite extreme reached in the forenoon hours of the following day,—(a movement of the north end of the magnet from west to east in the extra-tropical parts of the northern magnetic hemisphere, and from east to west in the same parts of the southern magnetic hemisphere,)—is found to be interrupted in both hemispheres by a minor retrogression (of variable duration); after which the previous direction is resumed. The phenomenon of this "nocturnal episode," as it has been not inappositely called, appears to have been first observed and noticed by M. de Humboldt himself, in conjunction with M. Gay Lussac, at Rome, in 1805 (p. 127); but although a very important feature, it seems to have been unaccountably lost sight of, for it is wholly unnoticed by M. Arago in 1836 (Annuaire, p. 283), when stating in detail the diurnal march of the declination in the northern and southern hemispheres. On the reception at Woolwich of the earliest observations of the British colonial observatories, it was at once perceived, from the examination of

the records at Toronto and Hobarton, that the nocturnal retrogression is a persistent feature in both hemispheres,— and it was at the same time recognised that the hours at which this interruption of the otherwise apparently regular progression took place, were those which were most affected by the *disturbances;* and that (in both hemispheres), the interruption was precisely such as *might* be occasioned by them, and might consequently be made to disappear if their influence could be wholly eliminated. The following extract from the first volume of the "Toronto Observations," published in 1845, will show that such was the view taken even at that early period. "The influence of the disturbances must now be regarded as a regular component part of the diurnal variation itself (mean quantities being considered). They now, therefore, pass from the domain of that portion of the observed phenomena to which we give the name of accidental or irregular, (from our present ignorance of the laws which regulate them), to be classed with the other portion in which we recognise laws of order and succession, though as yet we may not be able to assign either causes or precise numerical values. On the one hand we cannot with propriety overlook their influence on the diurnal variation, because though they are of only occasional occurrence, they yet form a permanent and regular part of its *mean* value; diminishing (in mean values) the easterly direction of the north end of the magnet in the forenoon, and increasing it in the evening. On the other hand, it becomes an object of much interest to learn what portion of the diurnal variation is thus due to what is apparently an effect of a distinct

and special cause, and how the residual portion of the variation would be affected by its separation; and this interest is increased when, even on a slight examination, we perceive that the hours which are chiefly affected by disturbance are those hours of the night when the continuous, and otherwise regular, easterly progression of the diurnal variation suffers interruption, occasioning a double, and even sometimes in the winter months a triple, alternation of easterly and westerly movement." (Tor. Obs. vol. i. p. xxi.)

The view thus early taken has been strengthened by the results of the observations in succeeding years. The third volume of the same work contains a discussion of the diurnal variation obtained from five years of hourly observation at Toronto, wherein it is shown (pp. lxxxvi—lxxxix) that when all the disturbances are allowed to remain in the body of the observations, the nocturnal westerly retrogression commences a little after 9 P.M., and the easterly point which the declination had reached at that hour is not regained until after 4 A.M., having been at 2 P.M. 0′.7 west of that point: but that, when the larger disturbances, or those which equalled or exceeded 5′ on either side of the mean or normal at the same hour in the same month, are eliminated, the westerly retrogression is diminished in duration to the interval between 11 P.M. and 3 A.M., and in value to 0′·19 at 2 P.M.; and further, that if we proceed on the assumption that by abstracting the disturbances equalling or exceeding 5′, we may have eliminated *half* of the whole influence of the causes to which the larger disturbances are due (which is certainly no unreasonable supposition), the westerly retrogression becomes almost wholly obliterated, and the

residual diurnal variation is virtually a single progression with but one maximum and one minimum.

The belief that the "nocturnal episode" is, in great part, at least, if not wholly, the effect of the disturbances, is further strengthened by the analogous facts of the diurnal variation of the total magnetic force at Toronto, discussed in pp. xciii—xcv of the same volume. When the diurnal variation of this element is obtained from the whole of the observations, *including the disturbances,* two well marked maxima and minima appear in the twenty-four hours; but by eliminating the disturbances in a greater or less degree, by a process similar to that adopted in the declination, one of the two maxima and one of the two minima diminish in proportion to the degree in which the disturbances are removed, giving full reason to believe that by eliminating their influence altogether, the residual diurnal variation would be reduced to the simple form of a single progression in twenty-four hours.

There is also reason to believe that the supposed anomalies in the turning hours of the diurnal-variation which have been observed in the high latitudes, and which are adverted to in pages 129 and 130 of this volume, are produced by the disturbances. At the only station in the high latitudes where the large disturbances have been separated, viz. Point Barrow (Phil. Trans. 1857, Art xxiv.), the effect of the separation has been to remove the mask by which the true features of the solar-diurnal variation were concealed, and to restore its turning hours to accordance with the order of the phenomena observed generally in the same hemisphere.

NOTES.

(1) p. 14.—Kosmos, Bd. iii. S. 107 (English edition, p. xv. Note 94); compare also Bd. ii. S. 464 and 508 (English edition, p. lxxviii. and cxiii.).

(2) p. 18.—"La loi de l'attraction réciproque au carré de la distance est celle des émanations qui partent d'un centre. Elle paraît être la loi de toutes les forces dont l'action se fait apercevoir *à des distances* sensibles; comme on l'a reconnu dans les forces électriques et magnétiques. Une des propriétés remarquables de cette loi est que, si les dimensions de tous les corps de l'univers, leurs distances mutuelles et leurs vitesses venaient à croître ou à diminuer proportionnellement, ils décriraient des courbes entièrement semblables à celles qu'ils décrivent: en sorte que l'univers, réduit ainsi successivement jusqu'au plus petit espace imaginable, offrirait toujours les mêmes apparences aux observateurs. Ces apparences sont par conséquent indépendantes des dimensions de l'univers, comme, en vertu de la loi de la proportionalité de la force à la vitesse, elles sont indépendantes du mouvement absolu qu'il peut y avoir dans l'espace." Laplace, Exposition du Syst. du Monde (5me éd.), p. 385.

(3) p. 19.—Gauss, Bestimmung des Breitenunterschiedes zwischen den Sternwarten von Göttingen und Altona, 1828, S. 73. By a singular accident, the two observatories are, within less than the width of a house, in the same meridian.

(4) p. 19.—Bessel, über den Einfluss der Unregelmässigkeiten der Figur der Erde auf geodätische Arbeiten und ihre Vergleichung mit astronomischen Bestimmungen, in Schumacher's Astron. Nachr., Bd. xiv. No. 329, S. 270; and also Bessel and Bāeyer, Gradmessung in Ostpreussen, 1838, S. 427—442.

(5) p. 20.—Bessel, über den Einfluss der Veranderungen des Erdkörpers auf die Polhöhen, in Lindenau and Bohnenberger, Zeitschrift für Astronomie, Bd. v.

1818, S. 29. "The weight of the Earth expressed in pounds $= 9933 \times 10^{21}$, and the supposed displaced mass $= 947 \times 10^{14}$."

(6) p. 20.—The theoretical investigations of that period were followed by those of Maclaurin, Clairaut, D'Alembert, Legendre, and Laplace; to these should be added the theorem propounded in 1834 by Jacobi: that ellipsoids having three unequal axes may, under certain conditions, be as good "figures of equilibrium as the two earlier assigned ellipsoids of revolution." See, in Poggendorff's Annalen der Physik und Chemie, Bd. xxxiii. 1834, S. 229—233, the memoir of Jacobi, removed by an early death from his friends and admirers.

(7) p. 21.—The first exact comparison of a considerable number of measurements of arcs (*i. e.* the Quito, two Indian, French, English, and recent Lapland arcs) was undertaken, with much success, in 1819, by Walbeck at Abo. He found the mean values of $\frac{1}{302 \cdot 781}$ for the ellipticity, and $57009^t,758$ for the length of a mean degree of the meridian. This memoir, entitled "De Forma et Magnitudine Telluris," has not, unfortunately, been published entire. At the recommendation of Gauss, Eduard Schmidt, in his valuable "Lehrbuch" of mathematical geography, has repeated the investigation with improvements, taking into account the higher powers of the ellipticity as well as the latitudes observed at intermediate points; and adding the Hanoverian arc, and the prolongation by Biot and Arago of the French arc to Formentera. The results, made successively more perfect, were published in three forms: in Gauss's "Bestimmung der Breitenunterschiede von Göttingen und Altona," 1828, S. 82; in Eduard Schmidt's "Lehrbuch der mathem. und phys. Geographie," 1829, Th. i. S. 183 and 194—199; and lastly, in the Preface to the same book, S. v. The final result is: Degree of the meridian, $57008^t \cdot 655$; ellipticity, $\frac{1}{297 \cdot 479}$. Bessel's first investigation was immediately preceded (1830) by Airy's important Memoir on the Figure of the Earth in the Encyclopædia Metropolitana, pp. 220 and 239, in the edition of 1849 (Semi-polar axis, 20853810 feet = 3261163·7 toises; semi-equatorial axis, 20923713 feet = 3272095·2 toises; meridian quadrant, 32811980 feet = 5131208·0 toises; ellipticity, $\frac{1}{298 \cdot 33}$). Our great Konigsberg astronomer, Bessel, was constantly occupied from 1836 to 1842 with calculations on the figure of the Earth, and as his earlier investigations were amended and improved by later ones, the mixture of results obtained at different times has become a fertile source of error in many writings. In the case of numbers, which are, by their nature, mutually dependent on each other, this kind of confusion, sometimes made worse by incorrect reduction of measures, (toises, metres, English feet, and miles 60 or 69 to an equatorial degree), is the more to be regretted as it causes enquiries which have cost much labour and

time to appear in a disadvantageous light. In the summer of 1837, Bessel published two memoirs; one on the influence of the irregularities of the Earth's figure on geodesical measurements, and their comparison with astronomical determinations; and the other on the axes of the elliptic spheroid of rotation which would correspond best with the existing measurements of arcs of meridians. (Schum. Astr. Nachr., Bd. xiv. No. 329, S. 269, and No. 333, S. 345.) The results of the calculation were:—Semi-major axis, $3271953^{t}\cdot854$; semi-minor axis, $3261072^{t}\cdot900$; length of a mean degree of the meridian, *i. e.* the ninetieth part of a quadrant of the Earth, in the direction perpendicular to the equator, $57011^{t}\cdot453$. An error of 68 toises, discovered by Puissant, in the mode of calculation employed by a commission of the French National Institut, 1808, in determining the distance of the parallels of Montjouy, near Barcelona, and Mola, in Formentera, occasioned Bessel to subject his first work on the dimensions of the Earth to a fresh revision, in 1841. (Schum. Astr. Nachr., Bd. xix. No. 438, S. 97—116.) The revision gave for the length of the Earth's quadrant $5131179^{t}\cdot81$,—(5130740 toises had been supposed in the first determination of the metre),—and for the mean length of a degree of the meridian $57013^{t}\cdot109$ (being $0^{t}\cdot611$ more than the degree of the meridian in 45° lat.). The numbers given in the text are the results of this, Bessel's last determination. The length of 5131180 toises as the quadrant of the meridian (with a mean error of $255^{t}\cdot63$), is equivalent to 10000856 metres; making the entire circumference of the Earth 40003423 metres (or 5390·98 German, or 21563·92 English geographical miles). The difference from the original assumption of the Commission des Poids et Mesures, according to which the metre should be the 40-millioneth part of the Earth's circumference, amounts, therefore, for the circumference, to 3423^{met}, or $1756^{t}\cdot27$, *i. e.* 0·46 of a German, or 1·84 of an English geographical mile. According to the earliest determinations, the length of the metre was fixed at $0^{t}\cdot5130740$; according to Bessel's latest determination, it should be $0^{t}\cdot5131180$. The difference for the length of the metre is therefore 0·038 Paris lines, making it, according to Bessel, 443334, instead of 443296 Paris lines, which is its present legal value. Compare also on this so-called "natural standard," Faye, Leçons de Cosmographie, 1852, p. 93.

(8) p. 23.—Airy, Figure of the Earth, in the Encycl. Metrop. 1849, p. 214—216.

(9) p. 23.—Biot, Astr. physique, t. ii. p. 482 and t. iii. p. 482. A very exact measurement of a parallel arc has been made by Corabœuf, Delcros, and Peytier, on the "Parallel of the Chain of the Pyrenees;" a work of the greater importance because it has led to the comparison of the levels of the Mediterranean and the Atlantic.

(^{10}) p. 24.—Kosmos, Bd. i. S. 175 (English edition, p. 158). "Il est très-remarquable qu'un astronome, sans sortir de son observatoire, en comparant seulement ses observations à l'analyse, eût pu déterminer exactement la grandeur et l'aplatissement de la terre, et sa distance au soleil et à la lune, élémens dont la connaissance a été le fruit de longs et pénibles voyages dans les deux hémisphères. Ainsi la lune, par l'observation de ses mouvements, rend sensible à l'astronomie perfectionnée *l'ellipticité* de la terre, dont elle fit connaître la *rondeur* aux premiers astronomes par ses éclipses." (Laplace, Expos. du Syst. du Monde, p. 230.) We have already noticed, in Bd. iii. S. 498 and 540 (English edition, p. 355 and cxxvii), an almost analogous optical proposal of Arago, founded on the remark that the intensity of the ash-coloured light (*i. e.* of the "earthlight" on the moon) might inform us as to the mean state of transparency of the whole of our atmosphere. Compare also Airy, in the Encycl. Metrop. p. 189 and 236, on the determination of the Earth's ellipticity from the moon's movements, and p. 231—235, on deductions of the Earth's ellipticity from the observed magnitudes of precession and nutation. According to Biot, precession and nutation could only give for the ellipticity limitary values ($\frac{1}{304}$ and $\frac{1}{578}$), very distant from each other. (Astron. physique, 3^e éd. t. ii. 1844, p. 463.)

(^{11}) p. 24.—Laplace, Mécanique céleste, éd. de 1846, t. v. p. 16 and 53.

(^{12}) p. 24.—Kosmos, Bd. i. S. 421. Anm. 1 (English edition, p. xliii. Note 131). The application of the isochronism of the vibrations of a pendulum in Arabian astronomical writings was first made known by Edward Bernard in England. See his letter from Oxford, April, 1683, to Dr. Robert Huntington, in Dublin. (Phil. Trans. vol. xii. p. 567.)

(^{13}) p. 24.—Fréret, de l'Étude de la Philosophie ancienne, in the Mém. de l'Acad. des Inscr. t. xviii. (1753) p. 100.

(^{14}) p. 25.—Picard, Mesure de la Terre, 1671, art. 4. It is hardly probable that the conjecture expressed at the Paris Academy before 1671, of a variation of the intensity of gravity with the latitude (Lalande, Astronomie, t. iii. p. 20, § 2668), should have belonged to the great Huygens. Huygens had indeed presented his "Discours sur la cause de la Gravité" to the Academy in 1669; it is not, however, in this memoir, but in the "additamentis," one of which must have been completed after the appearance of Newton's Principia, as it refers to it—therefore, after 1687—that Huygens speaks of the shortening of the second's pendulum observed by Richer at Cayenne. He says: "Maxima pars hujus libelli scripta est, cum Lutetiæ degerem (to 1681), ad cum usque locum, ubi de alteratione, quæ pendulis accidit e motu Terræ." Compare the explanation given by me in Kosmos, Bd. ii. S. 520, Anm. 2 (English edition, p. cxxv. Note 542). The observations made by Richer at Cayenne were not published until fully six

years after his return, and, what is more surprising, no notice of his important double observation, of the clock pendulum and of a simple second's pendulum, occurs in the Proceedings of the Académie des Inscriptions during this long interval. We do not know when Newton, whose earliest theoretical speculations on the figure of the Earth were antecedent to 1665, first became aware of Richer's results. Picard's arc measurement, although published in 1671, only came very late (1682), and indeed accidentally, in conversation at a meeting of the Royal Society, to Newton's knowledge. It exercised, as Sir David Brewster has shown (Life of Newton, p. 152), an exceedingly important influence on his determination of the Earth's diameter and the relation of the fall of bodies on our planet to the force which governs the moon in her course. We may suppose a similar influence to have been exercised on Newton's ideas by the knowledge of the elliptic figure of Jupiter, which was recognised by Cassini previous to 1666, but first described by him in 1691, in the Mémoires de l'Académie des Sciences, t. ii. p. 108. May Newton have known anything of an earlier publication, some sheets of which were seen by Lalande in Maraldi's hands ? (Compare Lalande, Astr. t. iii. p. 335, § 3345, with Brewster's Life of Newton, p. 162, and Kosmos, Bd. i. S. 420, Anm. 99; English edition, p. xlii. Note 129.) In the contemporaneous labours of Newton, Huygens, Picard, and Cassini, the great delay in publication which was then customary, and the frequent accidental delays in communications, render it very difficult to arrive at any well-assured traces of the transmittance or exchange of scientific ideas.

([15]) p. 26.—Delambre, Base du Syst. métrique, t. iii. p. 548.

([16]) p. 26.—Kosmos, Bd. i. S. 422, Anm. 3 (English edition, p. xlv. Note 133); Plana, Opérations géodésiques et astronomiques pour la Mesure d'un Arc du Parallèle moyen, t. ii. p. 847 ; Carlini, in the Effemeridi astronomiche di Milano per l'anno 1842, p. 57.

([17]) p. 26.—Compare Biot, Astronomie physique, t. ii. (1844) p. 464, with Kosmos, Bd. i. S. 424, end of Anm. 3 (English edition, Note 133), and Bd. iii. S. 432 (English edition, p. 310), where I notice the difficulties which the comparison of the planet's time of rotation with its observed ellipticity presents. Schubert (Astron. Th. iii. S. 316) had called attention to this difficulty. Bessel, in his memoir "Ueber Maass und Gewicht," says expressly that "the assumption of gravity remaining always the same at a place where it has been observed, appears in some degree uncertain, from the knowledge we have acquired of the slow changes of level of considerable portions of the Earth's surface."

([18]) p. 26.—Airy, in his excellent Memoir on the Figure of the Earth (Encycl. Metrop. 1849, p. 229), counted, in the year 1830, fifty different stations at which well-assured results had been obtained; and fourteen others where the results

(obtained at earlier periods by Bouguer, Legentil, Lacaille, Maupertius, and La Croyère) could not be looked upon as having nearly the same degree of exactness.

([19]) p. 28.—Biot and Arago, Recueil d'Observ. géodésiques et astronomiques, 1821, p. 526—540, and Biot, Traité d'Astr. phys. t. ii. 1844, p. 465—473.

([20]) p. 28.—Idem, p. 488. Sabine (Exper. for determining the Variation in the Length of the Pendulum vibrating Seconds, 1825, p. 352) found from his thirteen stations, so widely dispersed over the northern hemisphere, $\frac{1}{288 \cdot 3}$; and from the same with the addition of all the pendulum stations of the British Survey and of the French arc of the meridian (from Formentera to Dunkirk)—from the comparison therefore, in all, of 25 points of observation—almost the same result, viz. $\frac{1}{288 \cdot 9}$. At a considerable distance from the above stations (situated on the two sides of the Atlantic), the pendulum lengths found in the meridians of Petropaulowski and Sitka, give, as Lütke has remarked, a still much higher ellipticity : $\frac{1}{267}$. Bessel, with his peculiar lucidity, has shown analytically, in his investigations on the length of the simple second's pendulum (S. 32, 63, and 126—129), how the theory of the influence of the air surrounding the pendulum which was previously generally received and employed, leads to an error in calculation, and renders a correction necessary, on account of the difference of the loss of weight of solid bodies when they are immersed in a fluid, either in a state of repose or in vibration. Such a correction was somewhat obscurely pointed to in 1786, by the Chevalier de Buat. Bessel says, "If a body moves in a fluid (air), the latter becomes part of the moving system; and the moving force must be imparted, not only to the particles of mass of the solid body put in motion, but also to all the particles of mass of the fluid which are put in motion." On the experiments of Sabine and Baily, to which Bessel's practically important pendulum correction (reduction to a vacuum) gave occasion, see John Herschel in his Memoir of Francis Baily, 1845, p. 17—21.

([21]) p. 28.—Kosmos, Bd. i. S. 175 and 422, Anm. 2 (English edition, p. 158 ; Note 132). Compare for the phenomena in islands, Sabine, Pendulum Exper. 1825, p. 237 ; and Lütke, Obs. du Pendule invariable, exécutées de 1826—1829, p. 241. The same work contains a remarkable table of the kinds of rocks at sixteen pendulum stations (p. 239) from Spitsbergen (79° 50′ N. lat.) to Valparaiso (in 33° 2′ S. lat.). [See also Sabine, Pend. Exper. 1825, p. 338 ; in which is the first table of this description, containing thirteen stations.—Ed.]

([22]) p. 29.—Kosmos, Bd. i. S. 424, Anm. 5 (English edition, Note 135). Eduard Schmidt (Mathem. und phys. Geographie, Th. i. S. 394) has taken from the many pendulum observations made in the corvettes *Descu-*

bierta and *Atrevida*, under the command of Malaspina, thirteen stations belonging to the southern hemisphere, and found, on the mean, an ellipticity of $\frac{1}{280 \cdot 34}$. Mathieu also derived from Lacaille's observations at the Cape of Good Hope, and in the Isle of France, compared with Paris, $\frac{1}{284 \cdot 4}$; but the measuring apparatus of that period did not offer the security afforded by that of Borda and Kater, and the later methods of observation. This is the place for mentioning the fine experiments of Foucault, so honourable to the sagacity of the inventor, which have given a visible proof of the rotation of the Earth on its axis by means of the pendulum, its plane of vibration turning slowly from east to west. (Comptes rendus de l'Acad. des Sciences, séance du 3 février, 1851, t. xxxii. p. 135.) To obtain deviations to the eastward, as in the experiments on falling bodies of Benzenberg and Reich on steeples and in shafts, a very considerable height of fall is required; whereas Foucault's apparatus renders the rotation of the Earth sensible with a length of pendulum of six feet. Phenomena which are explained by the rotation of the Earth (as the march of Richer's clock at Cayenne, diurnal aberration, deflection of projectiles, and trade winds), are not to be placed in comparison with that which can at all times be called forth by Foucault's apparatus, and of which the members of the Academia del Cimento seem to have had a conception, but not to have pursued it. (Antinori, in the Comptes rendus, t. xxxii. p. 635.)

(23) p. 30.—In Grecian antiquity, two parts of the Earth were pointed out as having, according to inferences drawn from the opinions which then prevailed, remarkable inflation or elevation of surface: the north of Asia and the country under the equator. "The high and naked Scythian plains," said Hippocrates (De Ære et Aquis, § xix. p. 72, Littré), "without being crowned with mountains, spread out and rise to beneath the Bear." The same belief had been attributed to Empedocles at a yet earlier epoch (Plut. de Plac. Philos. ii. 8). Aristotle (Meteor. i. 1 a 15, p. 66, Ideler) says, that the older meteorologists, who "made the sun pass, not under, but round the Earth, considered the swelling of the Earth towards the north to be the cause of the nocturnal disappearance of the sun, and thus of the occurrence of night." Also, in the compilation of the problems (xxvi. 15; Pag. 941, Bekker), the coldness of the north wind is attributed to the "height of the ground" in that quarter. In all these passages it is not mountains, but high plains, or general elevation of the land, which are referred to. I have already shown elsewhere (Asie Centrale, t. i. p. 58), that Strabo,—who is the only writer who employs the characteristic word ὀροπέδια for Armenia (xi. p. 522, Casaub.), for Lycaonia, inhabited by the wild ass (xii. p. 568), and for Upper India, and the gold country of the Derdans (xv. p. 706),—always distinguishes the difference of climate due to geographical

latitude from that which belongs to difference of elevation. "Even in southern regions," says the geographer of Amasia, "every high ground, even if it is a plain, is cold." (ii. p. 73.) Eratosthenes and Polybius adduce in favour of a very moderate temperature at the equator, not only the more rapid passage of the sun (Geminus, Elem. Astron. c. 13; Cleom. Cycl. Theor. i. 6), but also, and more especially, the swelling or elevation of the ground. (See my Examen crit. de la Géogr. t. iii. p. 150—152.) Both those writers, according to the testimony of Strabo (ii. p. 97), assert, that "the part of the Earth which is near the equator is the highest, and that for this reason it is also very rainy, because the winds, which change with the seasons, bring from the north a great amount of clouds, which hang upon the high land." Of these two beliefs of two great elevations of the ground, one in Northern Asia (the Scythian Europe of Herodotus), and the other in the equatorial zone, the first has maintained itself, with that pertinacity which belongs to error, for almost two thousand years, and has led to the geological fable of an uninterrupted high land of Tartary north of the Himalaya; while the second could only be supported for an *extra* tropical part of Asia, for the "high" or "mountain"-plain of Meru, or Mount Meru, celebrated in the oldest and noblest monuments of Indian poetry. (See Wilson's Dict. Sanscrit and English, 1832, p. 674, where Meru is interpreted "high plain.") I have thought it necessary to enter into these details, in order to refute the hypothesis of the ingenious Fréret, who, without quoting passages from Greek authors, and only alluding to a single one relating to tropical rains, interprets the belief in local elevations of the ground, as having reference either to a flattening of the Earth at the poles, or to the converse. "Pour expliquer les pluyes," said Fréret (Mém. de l'Acad. des Inscriptions, t. xviii. 1753, p. 112), "dans les régions équinoxiales que les conquêtes d'Alexandre firent connoître, on imagina des courans qui poussoient les nuages des pôles vers l'équateur, où, au défaut des montagnes qui les arrêtoient, les nuages l'étoient par la hauteur générale de la Terre, dont la surface sous l'équateur se trouvoit plus éloignée du centre que sous les pôles. Quelques physiciens donnèrent au globe la figure d'un sphéroide renflé sous l'équateur et aplati vers les pôles. Au contraire, dans l'opinion de ceux des anciens qui croyoient la Terre alongée aux pôles, le pays voisin des pôles se trouvoit plus éloigné du centre que sous l'équateur." I cannot find any evidence in antiquity to justify these statements. In the third section of the first book of Strabo (Pag. 48, Casaub.), it is said expressly, "The whole Earth, as Eratosthenes has said, is globular, but not as if turned by a turner" (an expression borrowed from Herodotus, iv. 36), "having many irregular deviations from so exact a form, occasioned by water, fire, earthquakes, subterranean gusts of wind (elastic vapours?), and other such

causes. The globular form of the entire earth follows from the arrangement of the whole, which is not altered by such minor disfigurements ; the little disappears in the great." Subsequently it is said, following always Groskurd's very successful version, that " the Earth, with the sea, is globular, the land and seas forming but one surface;" that " the rising of the land out of the water being inconsiderable, in comparison with the whole extent, must remain unnoticed. We do not suppose the form of the globe to be as if turned on a turning-lathe, or conforming to the exact measurement which an artist might make of an artificial ball ; but rather speak of its roundness as we might of the roundness of such a ball, judged of more roughly by the eye." (Strabo, ii. p. 112.) " The world is the work both of Nature and Providence : of Nature, inasmuch as all tends together towards a point in the middle of the whole, around which it arranges itself the less dense (water), outside that which is more dense (earth)." (Strabo, xvii. p. 809.) When the form of the Earth is spoken of among the Greeks (Cleom. Cycl. Theor. i. 8, p. 51), it is compared simply to a disc; flat, or having a depression in the middle; to a cylinder (Anaximander); to a cube; or to a pyramid ; and, finally (notwithstanding the long controversy of the Epicureans, who denied the attraction to the centre), it came to be generally regarded as a globe. The idea of the flattening at the poles, which we call compression or ellipticity, did not, however, present itself. The " longish " Earth spoken of by Democritus is only the " disc " of Thales, longer in one direction than in the other. The *το σχῆμα τυμπανοειδες*, an idea attributed particularly to Leucippus (Plut. de Plac. Philos. iii. 10 ; Galen. Hist. Phil. cap. 21 ; Aristotl. de Cœlo, ii. 13 ; Pag. 293, Bekker), is at the bottom of the representation of a hemisphere, or half-globe, with an even base, which, perhaps, designates the equator, while the curvature is regarded as the *οικουμενη*. A passage in Pliny (ix. 54), on pearls, illustrates this form ; while, on the other hand, Aristotle, Meteorol. ii. 5 a 10 (Ideler, t. i. p. 563), only offers a comparison of segments of a globe with the tympanum, as also appears from the Commentary of Olympiodorus (Ideler, t. i. p. 301). I have purposely not noticed in this review two passages very familiar to me (Agathemer, de Geographia, lib. i. cap. i. p. 2, Hudson); Eusebius (Evangel. Præparat. t. iv. p. 125, ed. Gaisford, 1843), because they show how inaccurately subsequent writers have often attributed to the ancients opinions which were, in truth, entirely strange to them. According to these passages, Eudoxus would have spoken of the Earth as a disc, having a length twice as great as its breadth ; as would also Dicearchus, the disciple of Aristotle, although he had actually proposed proofs of its globular form (Marcian. Capella, lib. vi. p. 192) ; while Hipparchus would have regarded the Earth as *τραπεζοειδης*, and Thales would have held it to be spherical !

([24]) p. 30.—Bessel, in a letter to myself, Dec. 1828, says: "It often appears to me as if the Earth's ellipticity was sometimes spoken of as uncertain, because too great exactness is demanded. If we take $\frac{1}{310}$, $\frac{1}{300}$, $\frac{1}{290}$, and $\frac{1}{280}$, the corresponding differences between the greater and the lesser radius are 10554, 10905, 11281, and 11684 toises. The change of 30 units in the denominator only alters 1130 toises in the polar radius; an amount which, viewed in relation to the visible inequalities of the Earth's surface, appears so immaterial, that I am really often astonished that the experiments should agree within such near limits. Detached observations, isolated in wide spaces, would indeed teach us little more than we know at present; but it would be important to unite all the measurements over the entire surface of Europe, bringing all the astronomically determined points into the operation." This, however, would still only show the form of the Earth in what may be termed the western peninsula, or projecting part of the great Asiatic continent, about 66° of longitude. The steppes of Northern Asia, even the central Kirghis Steppe, of which I have seen a considerable portion, are often hilly, and, on the whole, not to be compared in point of horizontality with the Pampas of Buenos Ayres and the Llanos of Venezuela. These South American plains being distant from the mountains, and covered with secondary and tertiary strata of very uniform and moderate density, the anomalies which might be presented by pendulum experiments at different parts of their surface would afford very pure, and, therefore, decisive results, as to the local constitution of the *deep interior terrestrial strata.* Compare my Ansichten der Natur, Bd. i. S. 4, 12, and 47—50.

([25]) p. 31.—Bouguer, who invited La Condamine to undertake experiments on the deflection of the plumb line by the Chimborazo, does not indeed mention Newton's proposal in his "Figure de la Terre," p. 364—394. Unfortunately, the best informed of the two travellers did not observe at opposite sides (east and west) of the great mountain, but (Dec. 1738) at two stations on the same side, one being south 61½° west (distant 4572 toises from the centre of the mountain-mass), and the other south 16° west (distant 1753 toises). The first was in a part well known to me, probably below the height where the small mountain-lake of Yana-Cocha is situated, and the other in the pumice-covered plain of the Arenal. (La Condamine, Voyage à l'Équateur, p. 68—70.) Contrary to all expectation, the deflection indicated by the star altitudes was only 7″·5; which was attributed by the observers themselves to the difficulties attendant on observations made so near the limits of perpetual snow, the inexactness of the instruments, and, above all, to supposed great cavities in the colossal trachytic mountain. I have expressed, on geological grounds, considerable doubts as to the justness of the assumption of these great cavities and consequent small mass of

the trachytic dome of Chimborazo. To the south-south-east of Chimborazo, near the Indian village Calpi, is situated the eruption-cone of Yana-Urcu, which I examined carefully with Bonpland, and which is certainly of more recent origin than the elevation of its giant dome-shaped neighbour. We found nothing resembling a crater in the latter. See the ascent of Chimborazo in my "Kleinere Schriften," Bd. i. S. 138.

([26]) p. 31.—Baily, Exper. with the Torsion Rod, for determining the mean Density of the Earth, 1843, p. 6; John Herschel, Memoir of Francis Baily, 1845, p. 24.

([27]) p. 32.—Reich, neue Versuche mit der Drehwage (New Experiments with the Torsion Balance), in the Abhandl. der mathem. physischen Classe der Kön.-Sächsischen Gesellschaft der Wissenschaften zu Leipzig, 1852, Bd. i. S. 405 and 418. The latest experiments of my excellent friend Reich are rather nearer the fine investigation of Baily. I have derived the mean (5·5772) from the series of experiments *a* and *b*: *a*. with the tin sphere and the longer and thicker copper wire, 5·5712, with a probable error of 0·0113; *b*. with the tin sphere, and the shorter and thinner copper wire, as well as with the tin sphere and the bifilar iron wire, 5·5832, with a probable error of 0·0149. Taking into account these probable errors of *a* and *b*, the mean is 5·5756. Baily's result (5·660), obtained indeed by more numerous experiments, might yet, however, give a rather too high density, as its apparent value seemed to increase as the spheres employed (glass or ivory) were lighter. (Reich, in Poggendorff's Annalen, Bd. lxxxv. S. 190. Compare also Whitehead Hearn, in the Phil. Trans. for 1847, p. 217—229.) The motion of the torsion beam was observed by Baily according to the method of Reich, by means of the image, reflected, as in the magnetic observations of Gauss, in a mirror attached to the middle of the beam. The highly important use of the mirror, which so greatly increases the exactness of the reading, was proposed so long ago as 1826, by Poggendorff (Annalen der Physik, Bd. vii. S. 121).

([28]) p. 33.—Laplace, Mécanique céleste, éd. de 1846, t. v. p. 57. The mean specific weight of granite is estimated at 2·7 at the most, as the specific weights of the biaxal white mica, and the green uniaxal, are from 2·85 to 3·1, and those of the rest of the constituents of the rock, quartz and felspar, are 2·56 and 2·65. Oligoclase itself is only 2·68, and although hornblende may be 3·17, syenite, in which felspar always predominates, still remains much under 2·8. As the weight of clay-slate is 2·69—2·78, as among limestones it is only in pure dolomites that it attains 2·88, chalk 2·72, gypsum and rock salt 2·3, I consider the density of the accessible continental crust of the Earth to be nearer 2·6 than 2·4. Laplace, on the assumption of the density increasing in arithmetical pro-

gression from the surface to the centre, and with the certainly erroneous assumption that the density of the outermost strata = 3, found, for the mean density of the whole Earth, 4·7647, which differs considerably from the results of Reich, 5·577, and Baily, 5·660; far more so than the probable errors of observation could at all account for. By a new discussion of Laplace's hypothesis, in an interesting memoir which is soon to appear in Schumacher's Astr. Nachrichten, Plana has arrived at the result that it is possible, by an alteration in the treatment of this hypothesis, to represent very approximately Reich's mean density of the Earth, together with my estimate of 1·6 as the mean density of the outermost stratum or surface of both land and sea, and the Earth's ellipticity, within the probable limits of the last-named element. He says: "Si la compressibilité des substances dont la Terre est formée a été la cause qui a donné à ses couches des formes régulières, à peu près elliptiques, avec une densité croissante depuis la surface jusqu'au centre, il est permis de penser que ces couches, en se consolidant, ont subi des modifications, à la vérité fort petites, mais assez grandes pour nous empêcher de pouvoir dériver, avec toute l'exactitude que l'on pourrait souhaiter, l'état de la Terre solide de son état antérieur de fluidité. Cette réflexion m'a fait apprécier davantage la première hypothèse, proposée par l'auteur de la *Mécanique céleste*, et je me suis décidé à la soumettre à une nouvelle discussion."

([29]) p. 33.—Compare Petit, "Sur la latitude de l'Observatoire de Toulouse, la densité moyenne de la chaîne des Pyrénées, et la probabilité qu'il existe un vide sous cette chaîne," in the Comptes rendus de l'Acad. des Sc. t. xxix. 1849, p. 730.

([30]) p. 34.—Kosmos, Bd. i. S. 183 and 427, Anm. 10 (English edition, p. 166, and Note 140).

([31]) p. 34.—Hopkins (Physical Geology), Reports of the British Association for 1838, p. 92; Phil. Trans. 1839, Pt. II. p. 381; and 1840, Pt. I. p. 193; Henry Hennessey (Terrestrial Physics), in the Phil. Trans. 1851, Pt. II. p. 504 and 525.

([32]) p. 34.—Kosmos, Bd. i. S. 249 and 450—452, Anm. 95 (English edition, p. 227, and Note 225).

([33]) p. 35.—The observations communicated by Walferdin are of the autumn 1847. They differ very little from the results (Kosmos, Bd. i. S. 181, and Anm. 8 (English edition, p. 163, and Note 138); Comptes rendus, t. xi. 1840, p. 707), which Arago obtained also with Walferdin's apparatus in 1840, at a depth of 505 metres, just as the borer had passed through the chalk and began to penetrate the gault.

([34]) p. 36.—According to manuscript communications from the mine captain

von Oeynhausen. Compare Kosmos, Bd. i. S. 416, Anm. 94, and S. 426, Anm. 8 (English edition, Notes 124 and 138); also Bischof, Lehrbuch der chem. und phys. Geologie, Bd. i. Abth. i. S. 154—163. In absolute depth, the boring at Mondorf, in the Grand Duchy of Luxembourg (2066 Fr. feet), comes next to that of Neu-Salzwerk.

(35) p. 37.—Kosmos, Bd. i. S. 426 (English edition, p. 406), and Mémoires de la Société d'Hist. Naturelle de Genève, t. vi. 1833, p. 243. The comparison of a great number of Artesian wells in the neighbourhood of Lille with those of St. Ouen and Geneva, might lead us to infer a more considerable influence of the conducting power of the strata, if we could be satisfied that the data were all equally accurate. (Poisson, Théorie mathématique de la Chaleur, p. 421.)

(36) p. 37.—In a table of 14 borings, of above 100 metres in depth, from the most different parts of France, Bravais, in his instructive encyclopedic memoir, "Patria," 1847, p. 145, cites *nine* in which the depth corresponding to an increase of temperature of 1° centigrade falls between 27 and 39 metres, varying from 5 to 6 metres on either side of the mean (32^{m}) given in the text. (Compare also Magnus in Poggend. Ann. Bd. xxii. 1831, S. 146.) On the whole, the increase of temperature appears to be more rapid in Artesian wells of very small depth;—although, in this respect, the very deep wells of Monte Massi in Tuscany, and Neuffen in the north-western part of the Swabian Alps, form remarkable exceptions.

(37) p. 38.—Quetelet, in the Bulletin de l'Acad. de Bruxelles, 1836, p. 75.

(38) p. 38.—Forbes, Exper. on the Temperature of the Earth at different Depths, in the Transactions of the Royal Society of Edinburgh, vol. xvi. 1849, Pt. II. p. 189.

(39) p. 39.—All the figures relating to the temperature of the Caves de l'Observatoire are taken from Poisson's Théorie Mathématique de la Chaleur, p. 415 and 462. On the other hand, the Annuaire météorologique de la France of Martins and Haeghens, 1849, p. 88, contains different corrections of Lavoisier's subterranean thermometer, by Gay-Lussac. On the mean of three readings (June to August), that thermometer gave 12°·193, when Gay-Lussac found the temperature 11°·843; the difference therefore being 0°·350.

(40) p. 39.—Cassini, in the Mém. de l'Acad. des Sciences, 1786, p. 511.

(41) p. 41.—Boussingault, "Sur la profondeur à laquelle on trouve dans la Zone torride la Couche de Température invariable," in the Annales de Chimie et de Physique, t. liii. 1833, p. 225—247. John Caldecott, astronomer to the Rajah of Travancore, and Captain Newbold in India, have objected to the method recommended in this memoir, and confirmed by so many exact results obtained in South America. Mr. Caldecott found at Trevandrum (Edinb. Trans.

vol. xvi. Pt. III. p. 379—393), the temperature of the ground at a depth of three feet and more (deeper, therefore, than Boussingault prescribes), 85° and 86° Faht. ; the mean temperature of the air being stated to be 80°·02 Faht. Newbold's experiments (Phil. Trans. for 1845, Pt. I. p. 133) gave, at a depth of one foot, at Bellary (in 15° 5′ lat.), 4° Faht. increase of temperature from sunrise to two hours after noon ; but at Cassargode (lat. 12° 29′), with a clouded sky, only 1½°. Were the thermometers duly protected, and the ground adequately screened from the direct influence of the sun's rays? Compare also J. D. Forbes, Exper. on the Temp. of the Earth at different Depths, in the Edinb. Trans. vol. xvi. Pt. II. p. 189. Colonel Acosta, the meritorious historian of New Granada, has recently made at Guaduas, on the south-western declivity of the highlands of Bogota, where the mean temperature of the year is 74·84 F. at a depth of one foot, and in a covered space, a long series of observations which fully corroborate Boussingault's statement. Boussingault writes: "Les observations du Colonel Acosta, dont vous connaissez la grande précision en tout ce qui intéresse la Météorologie, prouvent que, *dans les conditions d'abri*, la température reste constante entre les tropiques à une très-petite profondeur."

(42) p. 41.—On Gualgagoc (or Minas de Chota) and Micuipampa, see Humboldt, Recueil d'Observ. astron. vol. i. p. 324.

(43) p. 41.—Essai politique sur le Roy. de la Nouv. Espagne, (2e éd.) t. iii. p. 201.

(44) p. 43.—C. Von Baer, in Middendorff's Sibirischer Reise, Bd. i. S. 7.

(45) p. 44.—The Merchant Fedor Schergin, head of the comptoir of the Russo-American Trading Company, began, in the year 1828, to have a well sunk in the court of a house belonging to the Company. As down to the depth of ninety-six feet, which he reached in 1830, only frozen earth was found, and no water, he gave up the work, until Admiral Wrangel passed through Iakutsk on his way to Sitka, and, perceiving the great scientific interest which attached to piercing through the subterranean icy stratum, asked Mr. Schergin to continue the boring. In 1837, a depth of fully 382 Eng. feet had been reached, the ice still continuing.

(46) p. 45.—Middendorff, Reise in Sib. Bd. i. S. 125—133. "If," says Middendorff, "we exclude all cases where the depth reached falls short of 100 feet, because, according to experience hitherto in Siberia, all lesser depths are subject to annual variations of temperature, there still remain such anomalies or differences in the rate of increase of temperature that, while between 150 and 200 feet, it has been found so rapid as to give only 66 English feet for an increase of 1° Reaum. ; between 250 and 300 feet, the observations would give

217 such feet to one such degree. We are, therefore, induced to consider that the results of the observations hitherto obtained in the Schergin boring, or shaft, are by no means sufficient to determine, with certainty, the measure of the increase of temperature; but yet, that (notwithstanding great deviations which may be occasioned by differences in the heat-conducting power of the strata, and in the disturbing influence of water or air which may sink down from the surface) we may venture to say that, on the whole, the temperature increases 1° Reaum. for a descent of not more than 100 to 117 Eng. feet." The result of 117 Eng. feet, is the mean of six partial results, or augmentations of temperature from at every 50 feet between 100 and 382 feet depth in the shaft. If I compare the mean atmospheric temperature of the year at Iakutsk (− 8°·13 Reaum.) with the mean temperature given by observation of the ice at the lowest part of the shaft (−2°·40 Reaum.—greatest depth 382 Eng. feet), I find $66\frac{3}{5}$ Eng. feet for 1° Reaum. The comparison of the deepest part with the temperature 100 feet below the surface, gives 100 feet. From the sagacious numerical investigations of Middendorff and Peters on the rate of propagation of variations of atmospheric temperature, and on the maxima and minima of temperature (Middend. S. 133—157 and 168—175), it follows, that in the different borings, at the small depths of 7 to 20 or 21 feet in the upper portions of the borings, there is "an increase of temperature from March to October, and a decrease from November to April, because spring and autumn are the seasons at which the changes of atmospheric temperature are most considerable." (S. 142 and 145.) Even carefully covered-over mines in Northern Siberia cool gradually in the course of years, from the contact of the air with the sides of the shafts. In the Schergin shaft, however, in the course of eighteen years, this contact has occasioned scarcely half a degree Cent. (0·9 Faht.) diminution of temperature. A remarkable, and, as yet, unexplained phenomenon, which has also presented itself in the Schergin shaft, is an increase of temperature which has sometimes been perceived in winter, exclusively in the lower strata, and "without any demonstrable external influence." (S. 156 and 178.) A more extraordinary circumstance, as it appears to me, is that in the boring at Wedensk, on the Päsina, with an atmospheric temperature of −28° Reaum., − 2°·5 was found at the very small depth of between 5 and $8\frac{1}{2}$ feet! The isogeothermal lines, to the direction of which Kupffer's sagacious investigations first called attention (Kosmos, Bd. i. S. 445; English edition, Note 201), will probably long present many unresolved problems. The solution is particularly difficult where the complete piercing through the stratum of ground ice is a work of much time. The ground ice at Iakutsk can no longer be looked upon as a mere local phenomenon, as in the view of those who attributed it to a sinking of the

earthy strata through the agency of water, or a precipitation of earth from water. (Middend. S. 167.)

(47) p. 45.—Middendorff, Bd. i. S. 160, 164 and 179. In these numerical estimates and conjectures as to the thickness of the ground ice, an increase of temperature in arithmetical progression with the depth is assumed. Whether, at greater depths, the rate of increase of temperature may become slower, is theoretically uncertain ; and it is, therefore, not advisable to enter into calculations respecting the temperature at the centre of the Earth in current-exciting molten masses of various kinds.

(48) p. 46.—Schrenk's Reise durch die Tundern der Samojeden, 1848, Th. i. S. 597.

(49) p. 46.—Gustav. Rose, Reise nach dem Ural, Bd. i. S. 428.

(50) p. 47.—Compare G. von Helmersen's experiments on the relative conducting power of different rocks (Mém. de l'Académie de St. Pétersbourg ; Mélanges physiques et chimiques, 1851, p. 32).

(51) p. 47.—Middendorff, Bd. i. S. 166 compared with S. 179. "The limit of the ground ice appears to have, in Northern Asia, two southerly inflexions, one not deep on the Obi, and one very considerable on the Lena. The line runs from Beresow on the Obi towards Turuchausk on the Ienissei, then between Witimsk and Oleminsk, on the right bank of the Lena, and then, eastward, ascending to the north."

(52) p. 50.—The principal passage in which the magnetic chain of rings is spoken of is in the Platonic Ion, p. 533 D, E. ed. Steph. Subsequently, this propagation of the attracting influence was mentioned by Pliny (xxxiv. 14) and Lucretius (vi. 910), and also by Augustine (de Civitate Dei, xx. 4) and Philo (de Mundi Opificio, p. 32 D. ed. 1691).

(53) p. 51.—Kosmos, Bd. i. S. 194 and 435, Anm. 32; Bd. ii. S. 293—295, 307—322, 468, Anm. 59; and S. 481—482, Anm. 91—93.

(54) p. 51.—Compare Humboldt, Asie Centrale, t. i. p. xl.—xlii., and Examen crit. de l'Hist de la Géographie, t. iii. p. 35. Eduard Biot, who, partly alone and partly with the help of Stanislas Julien, has confirmed and enlarged, by laborious bibliographic studies, Klaproth's researches on the antiquity of the use of the magnetic needle in China, cites an older tradition, which, however, is first found mentioned by writers of the first centuries of the Christian era, according to which magnetic cars would have been used as early as under the Emperor Hoang-ti. This celebrated monarch is supposed to have reigned 2600 years before our era (*i. e.* a thousand years before the expulsion of the Hyksos from Egypt). Ed. Biot, "Sur la direction de l'Aiguille aimantée en Chine," in the Comptes rendus de l'Acad. des Sciences, t. xix. 1841, p. 362.

([55]) p. 52.—Kosmos, Bd. i. S. 194 and 435, Anm. 31 (English edition, p. 176 and Note 161). Aristotle himself (de Anima, i. 2) speaks only of the "animation" of the loadstone as an opinion of Thales. Diogenes Laertius, however, distinctly extends the opinion to amber, saying, "Aristotle and Hippias maintain from Thales' doctrine," &c. The sophist Hippias of Elis, who thought he knew everything, occupied himself with natural philosophy, and thus with the most ancient traditions of the physiologic school. The "attracting breath of air" which, according to the Chinese physicist Kuopho, "blows or breathes through loadstone and amber," reminds us, according to Buschmann's linguistic Mexican investigations, of the Aztec name for the magnet: "tlaihio-anani tetl," signifying "the stone which draws to itself by breath" (from "ihiotl," breath; and "ana," draw).

([56]) p. 52.—The information respecting this remarkable apparatus, extracted by Klaproth from Penthasaoyan, is found in greater detail in Mung-khi-pi-than; Comptes rendus, t. xix. p. 365. Why is it that in the last-named memoir, as also in a Chinese Herbal, it is said that the cypress points to the west and the magnetic needle points to the south? Is it intended to refer to a more or less luxuriant development of the branches according to "aspect" as respects the sun or some prevailing wind?

([57]) p. 58.—Kosmos, Bd. ii. S. 469—472 (English edition, Note 405). In the time of Edward III. of England, when, as Sir Nicholas Harris has shown (History of the Royal Navy, 1847, vol. ii. p. 180), it was customary to sail by the compass, then called "sailstone dial," "sailing needle," or "adamant," we see that in the expenses of fitting out "the king's ship the George," in the year 1345, mention is made of sixteen "hour-glasses" bought in Flanders. This, however, is by no means a proof of the use of the log. Hour-glasses (the "ampolletas" of the Spaniards) were used, as is evident from the statements of Enciso in Cespedes, long before the employment of the log, "Echando punto por fantasia" in the "corredera de los perezosos," *i. e.* without casting out a log.

([58]) p. 58.—Compare Kosmos, Bd. i. S. 427, Anm. 11, and 429, Anm. 14 (English edition, Notes 141 and 144); Bd. ii. S. 373. 381, 382, and 515, Anm. 70—72, and 517, Anm. 88 (English edition, p. 331, 332, and 339, 340, Notes 510. 512. and 528).

([59]) p. 59.—Compare Gilbert, Physiologia nova de Magnete, lib. iii. cap. 8, p. 124. That magnetism can be imparted to iron for a considerable time, was said in a general way by Pliny, but without mentioning rubbing (Kosmos, Bd. i. S. 430, Anm. 19; English edition, Note 149). Gilbert's derisive remark on the "vulgaris opinio de montibus magneticis aut rupe aliqua magnetica, de polo phantastico a polo mundi distante," is worthy of notice. The alterations

and progressive movement which take place in the magnetic lines were still wholly unknown to him: "varietas uniuscujusque loci constans est."

(60) p. 59.—Historia natural de las Indias, lib. i. cap. 17.

(61) p. 59.—Kosmos, Bd. i. S. 189; English edition, p. 171.

(62) p. 60.—I have shown, from very careful observations of the Inclination made by myself in the Pacific, what are the conditions under which the magnetic Inclination may be of important practical use in determining the latitude during the prevalence of the "garua" or fog, which, at certain seasons on the Peruvian coast, conceals the sun and stars. (Kosmos, Bd. i. S. 185 and 428, Anm. 14; English edition, p. 168 and Note 144.) The Jesuit Cabius, the author of the "Philosophia magnetica" (in qua nova quædam pyxis explicatur, quæ *poli elevationem* ubique demonstrat), directed attention to this subject in the first half of the 17th century.

(63) p. 60.—Edmund Halley, in the Phil. Trans. for 1683 vol. xii. No. 148, p. 216.

(64) p. 61.—Such lines, called by him "tractus chalyboeliticos," had also been drawn by Pater Christoph Burrus, at Lisbon, in a map which he offered at an exorbitant price to the King of Spain, as mentioned by Kircher in his Magnes, ed. 2. p. 443. The first Variation Chart ever constructed has been already mentioned in p. 56.

(65) p. 62.—Even twenty years after Halley had prepared, at St. Helena, his Catalogue of Southern Stars (in which, unfortunately, there are none below the 6th magnitude), Hevelius, in the "Firmamentum Sobescianum," boasted of not using a telescope, and of observing through longitudinal apertures. Halley had been present at some of these observations (to the exactness of which he gave undue praise) when he visited Dantzic in 1679. Kosmos, Bd. iii. S. 60, 106 (Anm. 2 and 3), 154, 317, and 355 (Anm. 13); English edition, p. 43, xiv. (Notes 91 and 92), 97, 221, and lxxix. Note 370.

(66) p. 62.—Traces of variations of the magnetic Declination on different days, and at different hours, had already been remarked in London by Hellibrand, 1634, and in Siam by Pater Tachard, 1682.

(67) p. 63.—Compare Kosmos, Bd. i. S. 432—435, Anm. 29; English edition, Note 159. The excellent construction of the Boussole d'Inclinaison first made by Lenoir, according to Borda's plan, the possibility which it gave of free and long vibrations of the needle, the very great diminution of the friction of the axles, and the steadiness and good means of adjustment of the instrument, which was provided with levels, first made it possible to obtain exact measurements of the differences of the Earth's magnetic force in different zones.

(68) p. 65.—The numbers placed first in the table (as, for example, 1803—

1806) indicate the date of the observations; the figures within brackets, which are added occasionally after the titles of the memoirs, show the date of the publication of the observations, which was often much later.

([69]) p. 69.—Malus (1808) and Arago (1811, chromatic) polarisation of light. See Kosmos, Bd. ii. S. 370 (English edition, p. 329).

([70]) p. 70. — Kosmos, Bd. i. S. 186 and 429, Anm. 17 (English edition, p. 169 and Note 147).

([71]) p. 72.—" Before the practice was adopted of determining *absolute values*, the most generally used scale (and which still continues to be very frequently referred to) was founded on the time of vibration observed by Mr. de Humboldt about the commencement of the present century, at a station in the Andes of South America, where the direction of the dipping-needle was horizontal—a condition which was for some time erroneously supposed to be an indication of the minimum of magnetic force at the Earth's surface. From a comparison of the times of vibration of Mr. de Humboldt's needle in South America and in Paris, the ratio of the magnetic force at Paris to what was supposed to be its minimum was inferred (1·348); and from the results so obtained, combined with a similar comparison made by myself between Paris and London in 1827 with several magnets, the ratio of the force in London to that of Mr. de Humboldt's original station in South America has been inferred to be 1·372 to 1·000. This is the origin of the number 1·372, which has been generally employed by British observers. By *absolute* measurements we are not only enabled to compare numerically with one another the results of experiments made in the most distant parts of the globe, with apparatus not previously compared, but we also furnish the means of comparing hereafter the intensity which exists at the present epoch with that which may be found at future periods." Sabine, in the Manual for the Use of the British Navy, 1849, p. 17.

([72]) p. 74. — The desirability of concerted simultaneous magnetic observation was first perceived by Celsius. Without speaking of the influence of the aurora upon the declination, which had been discovered, and even measured, by his assistant, Olav Hiorter, in March, 1741, Celsius wrote in the summer of the same year to Graham, to invite him to join with him in examining whether certain extraordinary perturbations, which the horary march of the declination needle underwent from time to time at Upsala, would also be observable at the same time in London. Simultaneity of disturbance would, he said, afford proof of the cause of perturbation extending over considerable spaces of the Earth's surface, and not being occasioned by accidental local influences. (Celsius, in Svenfka Vetenskaps Academiens Handlingar for 1740, p. 44; Hiorter, in the same work for 1747, p. 27.) When Arago had become aware that the magnetic perturba-

tions accompanying auroras extend to regions of the Earth where the auroral light is not seen, he, in 1823, arranged with our common friend Kupffer for simultaneous hourly observations being made at Paris and at Kasan, almost 47° east of Paris. Similar simultaneous observations of the declination were set on foot by me in 1828, by Arago, Reich, and myself, in Paris, Freiberg and Berlin. See Poggend. Ann. Bd. xix. S. 337.

([73]) p. 81.—The memoir of Rudolph Wolf, referred to in the text, contains his own daily observations of solar spots, from the 1st of January to the 30th of June, 1852, and a comparison of Lamont's periodical declination-variations with Schwabe's results on the frequency of the solar spots in the interval from 1835 to 1850. This memoir was presented on the 31st of July, 1852, at a meeting of the Society of Natural Sciences at Berne, while the more detailed memoir of Colonel Sabine (printed in the Phil. Trans. for 1852, Pt. I. p. 116—121) had been presented to the Royal Society of London at the beginning of March, and read at the beginning of May in the same year, *i. e.* 1852. According to the most recent examination of all the observations which have been made on the solar spots, Wolf finds the mean period, between 1600 and 1852, to be 11·11 years.

([74]) p. 83. — Kosmos, Bd. iii. S. 400 and 419, Anm. 30 (English edition, p. 290 and civ.; Note 489). Bismuth, antimony, silver, phosphorus, rock-salt, ivory, wood, slices of apple, and leather, when placed in the vicinity of a powerful magnet, all show diamagnetic repulsion, and equatorial, *i. e.* east and west, axiality. Oxygen (pure, or mixed with other gases, or condensed in the interstices of charcoal) is paramagnetic. In reference to crystallised bodies, see what has been discovered, in relation to the position of certain axes, by the sagacious Plücker. (Poggend. Ann. Bd. 73, S. 178 ; and Phil. Trans. for 1851, Art. I. § 2836—2842.) The repulsion by bismuth was first recognised, in 1778, by Brugmans, and, at a later period, more thoroughly examined by Le Baillif in 1827, and by Seebeck in 1828. Faraday himself (§ 2429—2431), Reich, and Wilhelm Weber, who, since 1836, has been so uninterruptedly active in the advancement of the knowledge of the Earth's magnetism, have brought forward the connection of diamagnetic phenomena with those of induction. (Poggend. Ann. Bd. 73, S. 241 and 253.) Weber tried to satisfy himself that diamagnetism has its source in Ampère's molecular currents. (Wilh. Weber, Abhandlungen über electro-dynamische Maasbestimmungen, 1852, S. 545—570.)

([75]) p. 84.—For producing this "polarity," the magnetic fluids in every particle of oxygen are separated by the Earth's "actio in distans," a certain amount, in a determinate direction, and with a determinate force. Every particle of oxygen thus represents a small magnet, and all these small magnets react upon

each other, as well as upon the Earth; and lastly, act in combination with the Earth upon an imaginary needle, placed anywhere within or without the atmosphere. We may compare the oxygen surrounding the Earth to an armature of soft iron applied to a natural or to a steel magnet; the magnet being supposed spherical like the Earth, and the armature a hollow sphere like the envelope of oxygen in the atmosphere surrounding the Earth. The degree of magnetic power which each particle of oxygen can receive from the Earth's constant magnetism, diminishes with increasing temperature and rarefaction of the gas. Now as the sun's course from east to west is followed by a constant increase of temperature and expansion, this must produce a modification in the magnetic relations of the Earth and its oxygenous envelope, which, in Faraday's opinion, is the source of a part of the variations of the observed elements of terrestrial magnetism. Plücker finds that, inasmuch as the degree of force with which a magnet acts upon oxygen is proportioned to the density of that gas, the use of the magnet affords a simple eudiometric means of recognising the presence of one or two hundredth parts of free oxygen in a mixture of gases.

([76]) p. 86.—Kosmos, Bd. iv. S. 10 and 11 (English edition, p. 10 and 11).

([77]) p. 87.—Kepler, in Stella Martis, p. 32 and 34. Compare therewith his "Mysterium cosmogr." cap. 20, p. 71.

([78]) p. 87.—Kosmos, Bd. iii. S. 416, Anm. 23 (English edition, Note 482), where, both in the original and in the translation, "Basis Astronomiæ" has been printed instead of, as it ought to be, "Clavis Astronomiæ." The passage (§ 226) in which the solar evolution of light is termed "a perpetual aurora," is not to be found in the first edition of the Clavis Astr. of Horrebow (Havn. 1730), but only in the later edition, contained in Horrebow's "Operum mathematico-physicorum," t. i. Havn. 1740, pag. 317, where there is a Second Part of the Clavis in which the passage occurs. Compare with Horrebow's view the entirely accordant views of Sir William and Sir John Herschel, Kosmos, Bd. iii. S. 45, 56 (Anm. 22), 256 and 262 (English edition, p. 35, xi., Note 68), 176, and Note 289.

([79]) p. 87.—Mémoires de Mathém. et de Phys. présentés à l'Acad. Roy. des Sc. t. ix. 1780, p. 262.

([80]) p. 88.—"So far as these four stations (Toronto, Hobarton, St. Helena, and the Cape), so widely separated from each other and so diversely situated, justify a generalisation, we may arrive at the conclusion, that at the local hour of seven and eight A.M. the magnetic declination is *everywhere* subject to a variation of which the period is a year, and which is everywhere similar in character and amount, consisting of a movement of the north end of the magnet from east to west between the northern and the southern solstice, and a return from west to

east between the southern and the northern solstice, the amplitude being about five minutes of arc. The *turning periods of the year* are not, as many might be disposed to anticipate, *those months in which the temperature at the surface of our planet, or of the subsoil, or of the atmosphere* (as far as we possess the means of judging of the temperature of the atmosphere) *attains its maximum and minimum.* Stations so diversely situated would indeed present in these respects *thermic conditions* of great variety: whereas uniformity in the epoch of the *turning* periods is a not less conspicuous feature in the annual variation than is similarity of character and numerical value. At all the stations the *solstices* are the turning periods of the annual variation at the hour of which we are treating. The only periods of the year in which the diurnal or horary variation at that hour does actually disappear, are at the *equinoxes*, when the sun is passing from the one hemisphere to the other, and when the magnetic direction in the course of its annual variation from east to west, or vice versâ, coincides with the direction which is the mean declination of all the months and of all the hours. The *annual variation* is obviously connected with, and dependent on, the *Earth's position* in its orbit relatively to the sun, around which it revolves; as the *diurnal variation* is connected with, and dependent on, the *rotation of the Earth* on its axis, by which each meridian successively passes through every angle of inclination to the sun in the round of twenty-four hours." Sabine, On the annual and diurnal Variations (Observations made at the Magn. and Meteorol. Observatory at Toronto, vol. ii. p. xvii—xx.). Compare also his Memoir on the annual Variation of the magnetic Declination at different Periods of the Day, in the Phil. Trans. for 1851, Pt. II. p. 635, and the Introduction to vol. i. of the Observations made at the Observatory at Hobarton, p. xxxiv—xxxvi.

(81) p. 88.—Sabine, On the Means adopted for determining the absolute Values, secular Change, and annual Variation of the terrestrial magnetic Force, in the Phil. Trans. for 1850, Pt. I. p. 216. Also in Sabine's Opening Address to the Meeting of the British Association at Belfast, in 1852, he says: — "It is a remarkable fact, which has been established, that the magnetic force is greater in both the northern and southern hemispheres in the months of December, January, and February, when the sun is nearest to the Earth, than in those of May, June, and July, when he is most distant from it: whereas, if the effects were due to temperature, the two hemispheres should be oppositely instead of similarly affected in each of the two periods referred to.

(82) p. 88.—Lamont, in Poggend. Ann. Bd. 84, S. 579.

(83) p. 89.—Sabine, On periodical Laws discoverable in the mean Effects of the larger magnetic Disturbances, in the Phil. Trans. for 1852, Pt. I. p. 121. (Kosmos, Bd. iv. S. 73; English edition, p. 78.)

(84) p. 89.—Kosmos, Bd. iii. S. 402 (English edition, p. 292).

(85) p. 89.—Kosmos, Bd. iii. S. 238 (English edition, p. 158).

(86) p. 90.—Kreil, Einfluss des Mondes auf die magnetische Declination, 1852, S. 27, 29 and 46.

(87) p. 91.—Kosmos, Bd. i. S. 407, Anm. 55, and, in regard to meteoric stones, S. 137; also Bd. iii. S. 594 (English edition, Vol. i. Note 85, and p. 122; Vol. iii. p. 421).

(88) p. 92.—Compare Mrs. Somerville, in her brief but lucid representation of terrestrial magnetism, founded on Sabine's writings, in vol. ii. p. 102 of her Physical Geography (2nd edition). Sir James Ross, who, on his great antarctic expedition, crossed this curve of weakest force, December, 1839, lat. 19° S., and long. 29° 13′ W., and who has the great merit of having been the first to determine its place in the southern hemisphere, terms it the "equator of least intensity." See his Voyage to the Southern and Antarctic Regions, vol. i. p. 22.

(89) p. 92. — "*Stations of an intermediate* character situated between the northern and southern magnetic hemispheres, partaking, although in opposite seasons, of those contrary features which separately prevail (in the two hemispheres) throughout the year." Sabine, in the Phil. Trans. for 1847, Pt. I. p. 53 and 57.

(90) p. 93. — The Pole of Intensity of Force is not the Pole of Verticity. (Phil. Trans. for 1846, Pt. III. p. 255.)

(91) p. 93. — Gauss, allgem. Theorie des Erdmagnetismus, § 31.

(92) p. 94. — Phil. Trans. vol. xxxiii. for 1724, 1725, p. 332 ("to try if the dip and vibrations were constant and regular").

(93) p. 94.—Novi Comment. Acad. Scient. Petropol. t. xiv. pro anno 1769, Pars II. p. 33. See also Le Monnier, Lois du Magnétisme comparées aux Observations, 1776, p. 50.

(94) p. 95.—The sign + prefixed to a latitude signifies "North," and the sign – "South" [In this translation the words North and South, or the letters N. and S., are employed for the same purpose.—Ed.]; and East and West signify East and West longitude from Paris, unless otherwise stated. [In this translation, on the other hand, East and West, or E. and W., signify East or West longitude *from Greenwich, unless otherwise stated.*—Ed.] In the section on Terrestrial Magnetism, from p. 80 to p. 153, wherever marks of quotation (" ") occur without any particular memoir of Colonel Sabine's being expressly referred to, either in the text or in the notes, it is to be understood that the passage is taken from my friend's manuscript communications to myself.

(95) p. 96. — Fifth Report of the British Association, p. 72; Seventh Report,

p. 64 and 68; Contributions to Terrestrial Magnetism, No VII. in the Phil. Trans. for 1846, Pt. III. p. 254.

(96) p. 97.—Sabine, in the Seventh Report of the Brit. Assoc. p. 77.

(97) p. 97.—Sir James Ross, Voyage in the Southern and Antarctic Regions, vol. i. p. 322. This great navigator crossed the line of greatest force twice between Kerguelen and Van Diemen's Islands; first in 46° 44′ S. lat., 128° 28′ E. long., where the force was 2·034, from whence it diminished to 1·824 at Hobarton (vol. i. p. 103 and 104); and a year afterwards, from the 1st of January to the 3rd of April, 1841, when we find, from the journals of the *Erebus*, that from 77° 47′ to 51° 16′ South latitude, and 175° 43′ to 136° 52′ East longitude from Greenwich, the intensity of the Earth's magnetic total force was always above 2·00, and even reached 2·07. (Phil. Trans. for 1843, Pt. II. p. 211—215.) Sabine's result for the one focus of the southern hemisphere (lat. 64°, long. 137° 30′ E.), which I have given in the text, is derived from Sir James Ross's observations from the 19th to the 27th of March, 1841, between 58° and 64° 26′ S. lat., and 128° 40′ and 148° 20′ E. long., "crossing the southern isodynamic ellipse of 2·00 about midway between the extremities of its principal axis." Contributions to Ter. Mag. in the Phil. Trans. for 1846, Pt. III. p. 252.

(98) p. 97.—Ross's Voyage, vol. ii. p. 224. According to the instructions given for the voyage, the two southern foci of maximum force were conjectured to be in 47° S. lat. 140° E. long., and in 60° S. lat. 235° E. long.

(99) p. 98.—Phil. Trans. for 1850, Pt. I. p. 201; Admiralty Manual, 1849, p. 16; Erman, Magnet. Beob. S. 437—454.

(100) p. 99.— On the map of the isodynamic lines in North America, in No. VII. of Sabine's Contributions to Terrestrial Magnetism, by an accidental error, 14·88 is the number given instead of 14·21; but the latter, which is the true number, is given in the text of the Memoir, p. 252. There is also a typographical error in the portion added to Note 158 in the English translation of Kosmos (Vol. i. p. 414), 13·9 being printed instead of, as it ought to be, 14·21.

(101) p. 99.— 15·60 is taken from No. VII. of Sabine's Contrib. p. 252. From the Table of the Observations of the *Erebus* (Phil. Trans. for 1843, Pt. II. p. 169 and 172), we see that some of the observations, taken on the ice in 77° 47′ S. lat., 172° 40′ W. long., even gave 2·124 in the arbitrary scale. The value of 15·60 in absolute scale supposes the intensity of the force at Hobarton to be 13·51; the latter value being to be regarded as provisional (Mag. and Met. Observations at Hobarton, vol. i. p. lxxv.), and having indeed been a little augmented in vol. ii. p. xlvi., where it is given at 13·56. In the

Admiralty Manual, p. 17, I find the force at the stronger southern focus altered accordingly to 15·8.

([102]) p. 99.—Sabine, in the English translation of Kosmos, Vol. i. p. 414.

([103]) p. 100.—See the interesting representation entitled: Map of the World, divided into hemispheres by a plane coinciding with the meridians of 100 and 280 E. of Greenwich, exhibiting the unequal distribution of the magnetic intensity in the two hemispheres, Plate V., British Association Reports for 1837, p. 72—74. Erman found the force almost always below 0·76 (very weak therefore) between 24° 25′ and 13° 18′ S. lat., and between 34° 52′ and 32° 42′ W. long. from Greenwich.

([104]) p. 100. — Kosmos, Bd. i. S. 193 and 435, Anm. 30 (English edition, p. 175 and Note 160).

([105]) p. 100.—Ross's Voyage in the Southern Seas, vol. i. p. 22 and 27. See also Kosmos, Bd. iv. S. 84, Anm. 88 (English Edition p. 92, and Note 88).

([106]) p. 100. — See Table of Sulivan's and Dunlop's Observations in Phil. Trans. 1840, Pt. I. p. 143. Their minimum, however, was not lower than 8·00.

([107]) p. 101.—We obtain 1:2·44 by comparing, in the absolute scale, 6·4 at St. Helena with 15·60 at the stronger southern focus; or 1:2·47 by comparison of St. Helena with the southern maximum augmented to 15·8 (Admiralty Manual, p. 17); 1:2·91 by comparing, in the relative scale, Erman's observation in the Atlantic (0·706) with the southern focus (2·06); and even 1:2·95, if we compare, in the absolute scale, the weakest force observed by Erman (5·35) with the highest result for the southern focus (15·8). A mean number would be 1:2·69. Compare for the intensity of the force at St. Helena (6·4 in absolute, or 0·845 in relative scale) the earliest observations by Fitz Roy (0·836), Phil. Trans. for 1847, Pt. I. p. 52, and British Association Report for 1837, p. 56.

([108]) p. 101. — Compare English translation of Kosmos, Vol. i. Editor's Note 158 p. liii.—lviii., and No. VII. of Contributions to Terrest. Magnetism, p. 256.

([109]) p. 102. — What can have led to the erroneous result obtained in the coal mines of Flenu, viz., that at a depth of 83 French feet the horizontal intensity increased 0·001? Journal de l'Institut, 1845, Avril, p. 146. In an English coal mine, at a depth of a thousand feet, Henwood found no increase of force. (Brewster, Treatise on Magnetism, p. 275.)

([110]) p. 103.—Kosmos, Bd. i. S. 418, Bd. iv. S. 36 (English edition, Vol. i. Note 124; Vol. iv. p. 36).

([111]) p. 103. — In my observations, a diminution of magnetic force with in-

creasing height results from the comparison of the Silla de Caracas (8105 feet above the sea; force 1·188) with the harbour of La Guayra (height 0; force 1·262), and with the town of Caracas (height 2484 feet; force 1·209); from the comparison of the town of Santa Fé de Bogota (height 8190 feet; force 1·147) with the Chapel of Nuestra Señora de Guadalupe (height 10,128 feet. force 1·127), placed, like a swallow's nest, on a steep precipice overhanging the town, and in the closest proximity to it; from the comparison of the volcano of Purace (height 13650 feet; force 1·077) with the mountain-village of Purace (height 8136 feet; force 1·087), and with the neighbouring town of Popayan (height 5466 feet; force 1·117); and from the comparison of the town of Quito (height 8952 feet; force 1·067) with the village of San Antonio de Lulumbamba (height 7650 feet; force 1·087), situated in an adjacent ravine, and exactly on the geographical equator. An opposite result was derivable from the most elevated site at which I ever made magnetic experiments of vibration, *i. e.* at a height of 14,960 feet on the side of the long-extinct volcano of Antisana, opposite Chussulongo. The observations had to be made in a large cave, and the great increase of force was no doubt caused by a local attraction of the rock (trachyte), as was the case in experiments made by Gay-Lussac and myself on the margin of the crater of Vesuvius, and in the crater itself. In the cave of Antisana I found the magnetic force raised to 1·188, it being scarcely 1·068 on the neighbouring elevated, but yet much lower, table-lands. The intensity of the force at the Hospice on the St. Gothard (1·313) was greater than that at Airolo (1·309), though less than at Altorf (1·322); but the force at the Ursern Loch (1·307) was less than at Airolo. So also Gay-Lussac and myself found the intensity of the force at the Hospice on Mont Cenis 1·344, that at Lans le Bourg, at the foot of Mont Cenis, 1·323, and at Turin 1·336. The greatest anomalies, as might naturally have been anticipated, were presented by the still active volcano of Vesuvius. When, in 1805, we found the magnetic force 1·274 at Naples, and 1·288 at Portici, we found it increased to 1·302 at the hermitage of San Salvador, and diminished to 1·193 (lower than any place in the whole district) in the crater of Vesuvius. Ferrugineous matter in the lavas, proximity of magnetic poles in particular pieces, and the probably, on the whole, weakening effect of the heating of the ground, all contribute to produce the most opposite local disturbances. Compare my Voyage aux Régions équinoxiales, t. iii. p. 619—626, and Mém. de la Société d'Arcueil, t. i. (1807) p. 17—19.

([112]) p. 103.—Kupffer's observations were not made at the summit of Mount Elbrouz, and only apply to the difference of elevation (4500 feet) between two stations, the Bridge of Malpa, and the slope of the Mountain of Kharbis, situated at no inconsiderable distance from each other in a horizontal line. On the ob-

jections which Necker and Forbes have raised as to the result, see vol. xiv. of the Transactions of the Royal Society of Edinburgh, 1840, p. 23—25. [All the elevations given in this and the preceding note are, as in the original, in French feet; it did not appear necessary to encumber the page by stating them in English feet likewise.—Ed.]

([113]) p. 104.—Compare Laugier and Mauvais, in the Comptes rendus, t. xvi. 1843, p. 1175, and Bravais, Observ. de l'Intensité du Magnétisme terrestre en France, en Suisse et en Savoie, in the Annales de Chimie et de Phys. 3e série, t. xviii. 1846, p. 214; Kreil, Einfluss der Alpen auf die Intensität, in the Denkschriften der Wiener Akad. der Wiss., mathem. naturwiss. Cl. Bd. i. 1850, S. 265, 279, and 290. It is the more remarkable that a very exact observer, Quételet, should have found, in 1830, the horizontal intensity at Geneva 1·080, at the Col de Balme 1·091, and at the Hospice on the Grand St. Bernard 1·096, being an increase with increasing elevation. Comp. Sir David Brewster, Treatise on Magnetism, p. 275.

([114]) p. 104.—Annales de Chimie, t. lii. (1805) pp. 86 and 87.

([115]) p. 104.—Arago, in the Annuaire du Bureau des Longitudes pour 1836, p. 287. Forbes, in the Edinb. Trans. vol. xiv. (1840) p. 22.

([116]) p. 105. — Faraday, Exper. Researches in Electricity, 1851, p. 53 and 77, § 2881 and 2961.

([117]) p. 106.—Christie, in the Phil. Trans. for 1825, p. 49.

([118]) p. 106.—Sabine, On the periodical Laws of the larger magnetic Disturbances, in the Phil. Trans. for 1851, Pt. I. p. 126; and the same, On the annual Variation of the magn. Declin., in the Phil. Trans. for 1851, Pt. II. p. 636.

([119]) p. 107.—Observ. made at the Magn. and Meteor. Observatory at Toronto, vol. i. (1840—1842) p. lxii.

([120]) p. 107.—Sabine, in Magn. and Meteor. Observations at Hobarton, vol. i. p. lxix. "There is also a correspondence in the range and turning hours of the diurnal variation of the total force at Hobarton and at Toronto, although the progression is a *double one* at Toronto, and a single one at Hobarton." The time of the maximum force is, at Hobarton, between 5 and 6 P.M., and that of the principal maximum at Toronto 6 P.M.; the time of the minimum at Hobarton is between 8 and 9 A.M., and that of the secondary minimum at Toronto at 10 A.M. Therefore, according *to local time*, the increase and decrease of the force follow the same hours in the two hemispheres; not the opposite ones, as in the case of the inclination and declination. On the causes of this phænomenon see p. lxix. of the above-cited work. (Compare also Faraday, On Atmospheric Magnetism, § 3027—3034.)

([121]) p. 107. — Phil. Trans. for 1850, Pt. I. p. 215 to 217; Magnetical Ob-

servations at Hobarton, vol. ii. (1852) p. xlvi. Compare what has been said above in Note 81. "The total force shows less difference at the opposite seasons of the year at the Cape of Good Hope than does the inclination." Magn. Observ. Cape of Good Hope, vol. i. (1851) p. lv.

(122) p. 108.—See the magnetic portion of my Asie Centrale, t. iii. p. 442.

(123) p. 108.—Sir John Barrow, Arctic Voyages of Discovery, p. 521 and 529.

(124) p. 108. — The highest inclination yet observed in Siberia was only 82° 16′; by Middendorff, on the River Taimyr, in 74° 17′ N. lat., and 95° 42′ E. long. (Middend. Sibir. Reise, Th. i. S. 194).

(125) p. 108. — Sir James Ross, Voyage to the Antarctic Regions, vol. i. p. 246. "I had long cherished the ambitious hope to plant the flag of my country on *both* the magnetic poles of our globe; but the obstacles which presented themselves being of so insurmountable a character, was some degree of consolation, as it left us no grounds for self-reproach." (p. 247.)

(126) p. 109.—Sabine, Pendulum Experiments, 1825, p. 476.

(127) p. 109. — Sabine, in the Phil. Trans. for 1840, Pt. I. p. 137, 139 and 146. For the movement of the African node, I follow the map appended to that memoir.

(128) p. 110. — I subjoin, as is always my custom, the elements of this not unimportant determination: Micuipampa, a small mountain-town in Peru, at the foot of the Cerro de Gualgayoc; 6° 44′ 25″ S. lat., 80° 53′ 3″ W. long. from Paris; elevation 11,140 French feet above the Pacific; magnetic inclination 0°·42 North (centesimal division of the circle). — Caxamarca, a town situated on a plain, 8784 French feet above the sea, in 7° 8′ 38″ S. lat., 5^h 23^m 42^s W. long. from Paris; inclination 0°·15 South.—Montan, a hacienda, surrounded by herds of lamas, in the heart of the mountains; 6° 33′ 9″ S. lat., 5^h 26^m 51^s W. long.; elevation 8042 French feet; inclination 0°·70 North.—Tomependa, in the province Jaen de Bracamoros, at the mouth of the Chinchipe at its junction with the Amazons; in 5° 31′ 28″ S. lat., 80° 57′ 30″ W. long.; elevation 1242 French feet; inclination 3°·55 North. — Truxillo, a town in Peru, on the sea-coast, in 8° 5′ 40″ S. lat., 81° 23′ 37″ W. long.; inclination 2°·15 South. Humboldt, Recueil d'Observ. astron. (Nivellement barométrique et géodésique,) vol. i. p. 316, No. 242, 244—254. For the bases of the astronomical determinations by star-altitudes and chronometers, see the same work, vol. ii. p. 379—391. By a singular accident, the result of my inclination observations in 1802 (7° 2′ S. lat., 81° 8′ W. long.), notwithstanding the effect of secular change, agrees not badly with Le Monnier's theoretical estimation. He said, "To the north of Lima, the magnetic equator must be found, in 1776, in $7\frac{1}{3}$°, or

at most in $6\frac{1}{2}^\circ$ South latitude!" (Lois du Magnétisme comparées aux Observations, Partie II. p. 59.) [In this Note the longitudes have not, as elsewhere, been converted into longitudes from Greenwich; they are all from Paris.—Tr.]

([129]) p. 110. — Saigey, Mém. sur l'Équateur magnétique d'après les Observ. du Capitaine Duperrey, in the Annales Maritimes et Coloniales, Dec. 1833, t. iv. p. 5. It was already remarked, in this memoir, that the magnetic equator is not an isodynamic line, but that the intensity of the magnetic force varies, at different parts of the line of no dip, from 1 to 0·867.

([130]) p. 110. — This position of the magnetic equator has been confirmed, for 1830, by Erman. On his return from Kamtschatka to Europe, he found the inclination almost null in 1° 30′ S. lat., 134° 57′ W. long.; in 1° 52′ S. lat., 137° 30′ W. long.; in 1° 54′ N. lat., 136° 5′ W. long.; and in 2° 1′ S. lat., 141° 28′ W. long. (Erman, Magnet. Beob. 1841, S. 536.) [In this Note, as in Note 128, the longitudes have all been left in longitudes from Paris, instead of being converted into longitudes from Greenwich, as is done wherever nothing is stated to the contrary. — Ed.]

([131]) p. 110.—Wilkes' United States Exploring Expedition, vol. iv. p. 263.

([132]) p. 111.—Elliot, in the Phil. Trans. for 1851, Pt. I. p. 287—331.

([133]) p. 111.—Duperrey, in the Comptes rendus, t. xxii. 1846, p. 804—806.

([134]) p. 113.—Letter from Arago to myself from Metz, 13th December 1827: "J'ai parfaitement constaté, pendant les aurores boréales qui se sont montrées dernièrement à Paris, que l'apparition de ce phénomène est toujours accompagnée d'une variation dans la position des aiguilles horizontales et d'inclinaison comme dans l'intensité. Les changements d'inclinaison ont été de 7′ à 8′. Par cela seul l'aiguille horizontale, abstraction faite de tout changement d'intensité, devait osciller plus ou moins vite suivant l'époque où se faisait l'observation; mais en corrigeant les résultats par le calcul des effets immédiats de l'inclinaison, il m'est encore resté une variation sensible d'intensité. En reprenant, par une nouvelle méthode, les observations diurnes d'inclinaison dont tu m'avais vu occupé pendant ton dernier séjour à Paris, j'ai trouvé, non par des moyennes, mais *chaque jour*, une variation régulière: l'inclinaison est plus grande le matin à 9^h que le soir à 6^h. Tu sais que l'intensité *mesurée avec une aiguille horizontale*, est au contraire à son *minimum* à la première époque, et qu'elle atteint son *maximum* entre 6^h et 7^h du soir. La variation totale étant fort petite, on pouvait supposer qu'elle n'était dûe qu'au seul changement d'inclinaison; et en effet la plus grande portion de la *variation apparente d'intensité* dépend de l'altération diurne de la composante horizontale: mais, toute correction faite, il reste cependant une petite quantité comme indice d'une *variation réelle d'intensité*." From another letter from Arago, written from Paris, March 1829, a short time before my

Siberian journey: "Je ne suis pas étonné que tu reconnais avec peine la variation diurne d'inclinaison dont je t'ai parlé, dans les mois d'hiver; c'est dans les mois chauds seulement que cette variation est assez sensible pour être observée avec une loupe. Je persiste toujours à soutenir que les changements d'inclinaison ne suffisent pas pour expliquer le changement d'intensité déduit de l'observation d'une aiguille horizontale. Une augmentation de température, toutes les autres circonstances restant les mêmes, ralentit les oscillations des aiguilles. Le soir, la température de mon aiguille horizontale est toujours *supérieure* à la température du matin; donc l'aiguille devrait, *par cette cause*, faire le soir, en un temps donné, moins d'oscillations que le matin; or elle en fait plus que le changement d'inclinaison ne le comporte: donc du matin au soir il y a une *augmentation réelle* d'intensité dans le magnétisme terrestre." Later, and far more numerous, observations at Greenwich, Berlin, St. Petersburg, Toronto in Canada, and Hobarton in Van Diemen's Land, have confirmed Arago's statement, made in 1827, that the horizontal force is greater in the evening than in the morning. At Greenwich, the principal maximum of the horizontal force is at 6^h, and the principal minimum at 22^h or 0^h; at Schulzendorf, near Berlin, maximum at 8^h, minimum at 21^h; at Petersburg, maximum 8^h, minimum $23^h\ 20^m$; at Toronto, maximum 4^h, minimum 23^h; speaking always of local time at each place. (Airy, Magn. Observ. at Greenwich for 1845, p. 13; for 1846, p. 102; for 1847, p. 241; Riess and Moser, in Poggend. Ann. Bd. xix. 1830, S. 175; Kupffer, Compte-rendu annuel de l'Obs. Central Magn. de St. Pétersb., 1852, p. 28; and Sabine, Magn. Obs. at Toronto, vol. i. 1840—1842, p. xlii.) At the Cape of Good Hope, and at St. Helena, the turning hours for the horizontal force are very different, and indeed almost opposite; the horizontal force at both those stations being weakest in the evening. (Sabine, Magn. Obs. at the Cape of Good Hope, vol. i. p. xl.; at St. Helena, p. 40.) It is not, however, so throughout the southern hemisphere. "The principal feature in the diurnal change of the *horizontal* force at Hobarton is the decrease of force in the forenoon, and its subsequent increase in the afternoon." (Sabine, Magn. Obs. at Hobarton, vol. i. p. liv.; vol. ii. p. xliii.

([135]) p. 114.—Sabine, Hobarton, vol. i. p. lxvii. and lxix.

([136]) p. 117.—Intensity of the total force at Hobarton, max. $5\frac{1}{2}^h$, min. $20\frac{1}{2}^h$; at Toronto, principal max. 6^h, principal min. 14^h; secondary max. 20^h, secondary min. 22^h. Compare Sabine, Toronto, vol. i. p. lxi. and lxii. with Hobarton, vol. i. p. lxviii.

([137]) p. 118. — Sabine, Report on the Isoclinal and Isodynamic Lines in the British Islands, 1839, p. 61—63.

([138]) p. 119. — Humboldt, in Poggend. Annalen, Bd. xv. S. 319—336.

Bd. xix. S. 357—391; and in the Voyage aux Régions équinox. t. iii. p. 616 and 625.

([139]) p. 119.—Hansteen, über jährliche Veränderung der Inclination, in Poggend. Ann. Bd. xxi. S. 403—429. Compare also, on the influence of the movement of the nodes of the magnetic equator, Sir David Brewster, Treatise on Magnetism, p. 247. Now that, through the abundance of observations at fixed stations, we have so vast a field for special inquiries, we find fresh and fresh complications arise in our search after regularity and law.

([140]) p. 119.—Phil. Trans. for 1841, Pt. I. p. 35.

([141]) p. 119.—Compare Sawelieff, in the Bulletin physico-mathématique de l'Acad. Imp. de St. Pétersb. t. x. No. 219, with Humboldt, Asie Centr. t. iii. p. 440.

([142]) p. 120. — Sabine, Magn. Observ. at the Cape of Good Hope, vol. i. p. lxv. If we might trust La Caille's dip observations in 1751 (he, indeed, never failed to invert the poles, but his needle did not move sufficiently freely), there would result for the Cape an increase of inclination of 10°·08′ in eighty-nine years.

([143]) p. 120. — Arago, in the Annuaire du Bureau des Long. pour 1825, p. 285—288.

([144]) p. 121. — I repeat here that all the European dips cited in this part of the text are in the usual graduation of the circle in 360°; it is only those observed by me on the American continent, prior to the month of June 1804 (Voy. aux Régions équinox. t. iii. p. 615—623), which refer to a centesimal graduation.

([145]) p. 123. — The Churprinz Mine at Freiberg in the Saxon Erzgebirge: the subterranean place of observation was on the 7th "Gezeugstreck," in the "Ludwiger Spathgang;" 80 "Lachter" east of the "Treibschacht," 40 "Lachter" west of the "Kunstschacht;" depth 133½ "Lachter." The observations were made with Freiesleben and Reich, at $2\frac{1}{2}^{h}$ P.M. (temperature of the mine 15°·6 Cent.); inclination with needle A 67° 37′·4; needle B 67° 32′·7; mean of the two needles in the mine 67° 35′·05. In the open air, at the surface of the ground, at a spot precisely vertical above the subterranean one, at 11 A.M., needle A gave 67° 33′·87, and needle B 67° 32′·12; mean of the two needles at the upper station 67° 32′·99 (temperature of the air 15°·8 Cent.). Difference between the results at the upper and lower stations 2′·06. Needle A, which, being the stronger, was always regarded by me with most confidence, gave the difference even higher than the mean of the two, being 3′·53 in favour of the lower station; the difference shown by needle B, taken alone, being scarcely sensible. (Humboldt, in Poggend. Ann. Bd. xv. S. 326.) The method which I

always employed has been described by me in detail in my Asie Centrale, p. 465—467. A mean result with each needle consists of sixteen readings. In estimating the probable value of determinations of such small quantities, it is important to consider the details of observation.

(146) p. 123.—Kosmos, Bd. i. S. 417 (English edition, Note 125).

(147) p. 123.—Humboldt, Voyage aux Régions équinox. t. i. p. 515—517.

(148) p. 125.—Erman, Reise um die Erde, Bd. ii. S. 180.

(149) p. 125.—Kosmos, Bd. iv. S. 53 (English edition, p. 55). Petrus Peregrini wrote to a friend that, in 1269, he had found the variation in Italy 5° east.

(150) p. 126.—Humboldt, Examen crit. de l'Hist. de la Géogr. t. iii. p. 29, 36, 38 and 44—51. Although Herrera (Dec. i. p. 23) says that Columbus had remarked that the magnetic variation (declination) is not the same in the day and at night, yet this statement by no means justifies us in attributing to the great discoverer a knowledge of the diurnal variation of the declination. From the genuine journal of Columbus, in his Voyages published by Navarrete, we learn from the part belonging to the 17th and 30th of September 1492, that he referred such changes to an "unequal movement of the pole-star and the pointers," called by him watchers or guards (guardas). (Examen crit. de l'Hist. de la Géogr. t. iii. p. 56—59.)

(151) p. 126.—Kosmos, Bd. iv. S. 60, Anm. 66; and S. 70, Anm. 72 (English edition, Note 66; and Note 72). The oldest printed observations in London are those of Graham, in the Phil. Trans. for 1724, 1725, vol. xxxiii. p. 96—107. (An Account of Observations made of the Horizontal Needle, at London, 1722—1723, by Mr. George Graham.) He said that the change in the declination depended "neither upon heat, nor cold, dry, or moist air."— "The variation is greatest between 12 and 4 in the afternoon, and least at 6 or 7 in the evening." These are not, indeed, the true turning hours.

(152) p. 127.—This is shown by numerous observations; by those of George Fuss and Kowanko, at the observatory belonging to the Greek convent in Pekin; Anikin at Nertchinsk, and Riddell at Toronto in Canada (all places having west declination); also by observations made by Kupffer and Simonoff, at Kasan; by Wrangel at Sitka, on the north-west coast of America, notwithstanding the frequent auroral disturbances; by Gilliss at Washington; Boussingault at Marmato, in South America; and by Duperrey at Payta, on the coast of Peru (all places having east declination). The mean declination was: at Pekin (Dec. 1831), 2° 15′ 42″ W. (Poggend. Ann. Bd. xxxiv. S. 54); at Nertchinsk (Sept. 1832), 4° 7′ 44″ W. (Poggend. Ann. Bd. xxxiv. S. 61); at Toronto (Nov. 1847), 1° 33′ W. (Compare Observ. at the Magn. and Met. Observa-

tory at Toronto, vol. i. p. xi.; and Sabine, in the Phil. Trans. for 1851, Pt. II. p. 636); Kasan (Aug. 1828), 2° 21′ E. (Kupffer, Simonoff, and Erman, Reise um die Erde, Bd. ii. S. 532); Sitka (Nov. 1829), 28° 16′ E. (Erman, Reise um die Erde, Bd. ii. S. 546); Marmato (Aug. 1828), 6° 33′ E. (Humboldt, in Poggend. Ann. Bd. xv. S. 331); Payta (Aug. 1823), 8° 56′ E. (Duperrey, in the Connaissance des Temps pour 1828, p. 252). At Tiflis the needle moves westward from 19^h to 2^h (Parrot, Reise zum Ararat, 1834, Th. II. S. 58).

([153]) p. 128.—Extracts from a letter written by me to Karsten, from Rome, June 22, 1805, printed in Hansteen's Magnetismus der Erde, 1819, S. 459, on the subject of "four movements of the magnetic needle, as it were four magnetic ebbs and flows analogous to the barometric periods." On the subject of the so long neglected nocturnal variations of the declination, compare Faraday, "On the Night Episode," § 3012—3024.

([154]) p. 128.—Airy, Magn. and Met. Observations made at Greenwich, 1845 (Results), p. 6; 1846, p. 94; 1847, p. 236. I quote from a letter, dated the 11th October 1836, from my friend, the distinguished director of the Berlin Observatory, Encke, to show how well the earliest assigned turning hours, both of the day and of the night, derived from corresponding observations at Berlin and Breslau, accord with those which have since been obtained from the fuller system of observation at the Greenwich and Toronto observatories:—"I do not think that there can be any doubt, in general, as to the existence of the nocturnal maximum, or inflection of the curve of the diurnal variation of the declination; Dove also inferred it from the Freiberg observations in 1830 (Poggend. Ann. Bd. xix. S. 373). In judging of the phænomena, graphical representations are much more advantageous than tables of numbers. In the former, great irregularities are easily seen to be such, and admit of a mean line being drawn; while in the latter the eye is frequently deceived, and takes a single striking irregularity for a real maximum or minimum. The period appears to be determined by the four turning hours:—

"Greatest east declination - - -	20^h - -	principal max. east.
„ west „ - - -	1 - -	principal min. east.
Secondary east „ - - -	10 - -	minor max. east.
„ west „ - - -	16 - -	minor min. east.

"The secondary minimum, or nocturnal elongation towards the west, falls, properly speaking, between 15^h and 17^h, being sometimes nearer to the one, and sometimes to the other of those hours." It is scarcely necessary to remark, that what Encke and I called minima to the east (at 1^h and 16^h) are the same which, at the British and American observatories founded in 1840, are

called maxima to the west; and that our "maxima to the east" (at 20^h and 10^h) correspond to their minima to the west. In order to show the diurnal march of the declination in the northern hemisphere, in its generality and analogy, I take the denominations employed by Sabine; and using the mean local time of each place, and beginning with the greatest westerly elongation we have:—

	Freiberg. 1829.	Breslau. 1836.	Greenwich. 1846—47.	Makerstoun. 1842—43.	Toronto. 1845—47.	Washington. 1840—42.
Maximum	1	1	2	0 40′	1	2
Minimum	13	10	12	10	10	10
Maximum	16	16	16	14 14	14	14
Minimum	20	20	20	19 14	20	20

In particular seasons, Greenwich has shown some remarkable differences. In 1847 there was, in the winter, only one maximum (at 2^h) and one minimum (at 12^h); in the summer there was a double progression, but the second minimum occurred at 14^h instead of at 16^h (p. 236); the greatest westerly elongation remained attached to 2^h in summer as well as in winter. In 1846 (p. 94) the secondary minimum was, in summer, as usual, at 20^h, but in winter at 12^h. The mean winter increase to the west continued in this year, without interruption, from midnight to 2^h. Compare also 1845 (p. 5). Makerstoun (Roxburghshire in Scotland) is the observatory due to the munificent scientific zeal of Sir Thomas Brisbane. (See J. A. Broun, Observations in Magnetism and Meteorology, made at Makerstoun in 1843, p. 221—227.) On the hourly day and night observations at St. Petersburg, see Kupffer, Compte rendu météor. et magn. à M. de Brock en 1851, p. 17. Sabine points out, in reference to his interesting and very sagaciously combined graphical representation of the hourly declination curve of Toronto (Phil. Trans. for 1851, Pt. II. Plate 27), how, previous to the small nocturnal movement to the west, which begins at 11^h and lasts till 15^h, there occurs a singular pause, lasting two hours, from 9^h to 11^h. "We find," Sabine remarks, "alternate progression and retrogression at Toronto twice in the twenty-four hours. In two of the eight quarters (1841 and 1842) the inferior degree of regularity during the night occasions the occurrence of a *triple max. and min.;* in the remaining quarters the turning hours are the same as those of the mean of the two years." (Obs. made at the Magn. and Meteor. Observatory at Toronto in Canada, vol. i. p. xiv. xxiv. 183—191 and 228; and Unusual Magn. Dist. Pt. I. p. vi.)

For the very complete observations at Washington, see Gilliss, Magn. and Met. Observations made at Washington, p. 325 (General Law). Compare there-

with Bache, Observations at the Magn. and Met. Observatory at the Girard College, Philadelphia, made in the years 1840—1845 (3 vols., containing 3212 pages), vol. i. p. 709, vol. ii. p. 1285, vol. iii. p. 2167 and 2702. Notwithstanding the vicinity of the two places (Philadelphia is only 1° 4′ north, and $0^h\ 7^m\ 33^s$ east of Washington), I find a difference in the times of the westerly secondary maximum and secondary minimum; the former being an hour and a half, and the latter two hours and a quarter, earlier in Philadelphia than in Washington.

([155]) p. 129.—I find instances of such small differences of time given by Lieutenant Gilliss, in his Magnetic Observations at Washington, p. 328. In the more northern latitude of Makerstoun in Scotland (lat. 55° 35′), there are fluctuations in the secondary minimum, which in the four last and three first months of the year takes place at 21^h, but in the other five months (April to August) at 19^h; contrary, therefore, to Berlin and Greenwich. (Broun, Obs. made at Makerstoun, p. 225.) The nocturnal movements of the needle, the *secondary* maximum and secondary minimum, speak most clearly against the regular diurnal variation of the declination being due to thermal variations; (the morning and principal minimum does take place not far from the minimum of temperature, and the principal maximum near the maximum of temperature). "There are two maxima and two minima of declination in the twenty-four hours, but only one maximum and one minimum of temperature in the same period." (Relshuber, in Poggend. Annalen der Physik und Chemie, Bd. 85, 1852, S. 416.) On the normal march of the magnetic needle in North Germany, see an excellent and faithful description in a Memoir of Dove's (Poggend. Ann. Bd. xix. S. 364—374).

([156]) p. 129.—Voyage en Islande et au Groënland, exécuté en 1835 et en 1836, sur la corvette "la Recherche;" Physique (1838), p. 214—225 and 358—367.

([157]) p. 129.—Sabine, Account of Pendulum Experiments, 1825, p. 500.

([158]) p. 130.—See Barlow's Account of the Observations at Port Bowen, in the Edinb. New. Phil. Journal, vol. ii. 1827, p. 347.

([159]) p. 130.—Professor Orlebar, at Oxford, at one time superintendent of the Magnetic Observatory established at the expense of the East India Company on the Island of Colaba, has tried to make out the complicated laws of the variation of the declination in the sub-periods ("Observations made at the Magn. and Met. Observatory at Bombay, in 1845;" Results, p. 2—7). I have been struck, in the first period, from April to August, by the agreement with the march of the needle in Middle Europe (W. min. $19\frac{1}{2}^h$, max. $0\frac{1}{2}^h$, min. $5\frac{1}{2}^h$, max. 7^h). The month of October is a transition period, for in November and Decem-

ber the diurnal variation scarcely reaches two minutes. Although Bombay is still 8° from the magnetic equator, the regularity of the turning hours is already hard to recognise. Wherever in nature different kinds of disturbing causes act in recurring, but wholly or partially unknown periods, then, inasmuch as the disturbances often either counteract or unequally reinforce each other, the regulating laws long remain concealed from us.

([160]) p. 131.—See the proofs in my Examen crit. de l'Hist. de la Géogr. t. iii. p. 34—37. The oldest statement of any particular amount of declination was by Keutsungchy, a writer of the beginning of the twelfth century, and was E. $\frac{5}{6}$ S. (Klaproth's Lettre sur l'Invention de la Boussole, p. 68.)

([161]) p. 131.—On the ancient intercourse of the Chinese with Java, according to the accounts of Fahian in the Fo-kue-ki, see Wilhelm v. Humboldt, "Ueber die Kawi-Sprache," Bd. i. S. 16.

([162]) p. 131.—Phil. Trans. for 1795, p. 340—349; for 1798, p. 397. The result which Macdonald derives from his observations at Fort Marlborough (situated above the town of Bencoolen, in Sumatra, 3° 47′ S. lat.), according to which the easterly elongation increases from 19^h to 5^h, does not seem to me to be quite warranted. After the hour of noon, the first observation ordinarily taken was either at 3^h, 4^h, or 5^h; and some detached observations, occasionally made at other hours, render it probable that in Sumatra, as at Hobarton, the turning hour from east to west was as early as 2^h. We have twenty-three months of declination observed by Macdonald (from June 1794, to June 1796), and it appears from them that at all seasons the east declination increased from $19\frac{1}{2}^h$ to noon, by a continuous movement of the needle from W. to E. We do not find in these observations any trace of the type of the phænomena of the northern hemisphere (Toronto movements), which prevails from May to September at Singapore; although Fort Marlborough is almost under the same meridian as Singapore, and only 5° 4′ of latitude from it; the Earth's equator, however, passing between the two places.

([163]) p. 132.—Sabine, Magn. Obs. made at Hobarton, vol. i. (1841 and 1842) p. xxxv. p. 2 and 148; vol. ii. (1843—1845) p. iii.—xxxv. and 172—344. Compare also Sabine, Obs. made at St. Helena; the same in the Phil. Trans. for 1847, Pt. I. p. 55, Pl. IV. and Phil. Trans. for 1851, Pt. II. p. 636, Pl. XXVII.

([164]) p. 133.—Kosmos, Bd. i. S. 190 (English edition, p. 172).

([165]) p. 134.—Sabine, Observations made at the Magn. and Meteor. Observatory at St. Helena in 1840—1845, vol. i. p. 30, and the same in the Phil. Trans. for 1847, Pt. I. p. 51—56. Pl. III. The regularity of the opposition in the two parts of the year, May to September following the type of the middle latitudes of the northern hemisphere, and October to February the type of the

middle latitudes of the southern hemisphere, is seen in the graphical representation, with all its striking distinctness, when we compare severally the form and inflexions of the curves of horary variation in the parts of the day from 14^h to 22^h, from 22^h to 4^h, and from 4^h to 14^h. Each inflexion above the line of mean declination corresponds to an almost equal or similar one below it (vol. i. Pl. IV. curves AA and BB). Even during the night the opposition is sensible, and it is a very interesting remark that when at St. Helena and the Cape of Good Hope the type is that of the northern hemisphere, there is seen at these very southern places the same anticipation of the turning hours as that which takes place in the same months at Toronto in Canada. Sabine, Observations at Hobarton, vol. i. p. xxxvi.

([166]) p. 135.—Phil. Trans. for 1847, Pt. I. p. 52 and 57, and Sabine, Observations made at the Magn. and Met. Observatory at the Cape of Good Hope, 1841—1846, vol. i. p. xii—xxiii. Pl. III. (Compare also Faraday's ingenious views on the causes of such phænomena in their dependence on the seasons of the year, in his "Experiments on Atmospheric Magnetism," § 3027—3068, and on the analogies with St. Petersburg, § 3017.) Near the southern shores of the Red Sea, a very diligent observer, M. d'Abbadie, is believed to have observed the same remarkable change of type in the march of the declination in the opposite parts of the year as that found at the Cape, St. Helena, and Singapore. (Airy, On the present State of the Science of Terrestrial Magnetism, 1850, p. 2.) Sabine remarks, in the Proceedings of the Royal Society, 1849, p. 821: "It results, from the present position of the four points of maximum force at the surface of the Earth, that the intermediate line of least force departs considerably in the Southern Atlantic from the middle or geographically equatorial portion of the globe, passing between the Cape and St. Helena, and consequently not far from either of those stations. The latitude of the Cape is 33° 56′ S. It is consequently not situated within the tropics, and the sun is throughout the year well to the north of its zenith, and therefore, according to M. de la Rive's thermal theory (Ann. de Chim. et de Phys. t. xxv. 1849, p. 310), the deviation should be in one and the same direction throughout the year. But the fact is not so, for the same contrariety in the direction of the diurnal variation takes place at the Cape as at St. Helena; the two portions of the year at which the opposite phænomena prevail are also identical at the two stations; and at both the change in the direction of the deviation takes place about the time when the sun crosses the equator; the deviation being to the west at both stations when the sun is north of the equator, and to the east when south of the equator."

([167]) p. 135.—Halley, "Account of the late surprising Appearance of Lights in the Air," in the Phil. Trans. vol. xxix. 1714—1716, No. 347, p. 422—428. Unfortunately, Halley's explanation of the Northern Light is connected with the

fanciful hypothesis propounded by him twenty-five years before (Phil. Trans. for 1693, vol. xvii. No. 195, p. 563), in which he supposed the Earth on which we dwell to be a hollow shell, enclosing an interior smaller globe also supporting human beings; and that "in order to make that inner globe capable of being inhabited, there might not improbably be contained some luminous medium between the balls, so as to make a perpetual day below." Then, supposing that the Earth's compression near the poles of rotation must cause the outer shell to be thinner there than at the equator, he considered that at certain seasons, and especially at the equinoxes, the interior luminous and magnetic fluid seeks a vent through fissures of the rocks composing the thinner crust near the poles; and this streaming forth of the bright fluid is, according to Halley, the phænomenon of the aurora. Experiments with iron-filings strewed over a spheroidal-shaped magnet (" a terrella"), served, he considered, to explain the direction of the luminous and coloured rays of the aurora. " As every one has his own rainbow, so every observer sees the corona at a different point." On the geognostic fancies of this ingenious, and in all his magnetical and astronomical works, solid philosopher, compare Kosmos, Bd. i. S. 178 and 425, Anm. 6 (English edition, p. 161 and Note 136).

(168) p. 137.—In the great fatigue of observing for many successive nights, Oltmanns and I were sometimes relieved or aided by very trustworthy observers—the architect Herr Mämpel, the geographer Herr Friesen, the highly informed mechanician Nathan Mendelsohn, and our great geognost Leopold von Buch. It is always a pleasure to me to name here, as in all my earlier writings, those who have kindly participated in my labours.

(169) p. 138.—The month of September, 1806, was remarkably rich in magnetic storms. To exemplify this, I subjoin an extract from my journal:

			h	m		h	m
$\frac{21}{22}$	Sept. 1806	from	16	36	to	17	43
$\frac{22}{23}$	"	"	16	40	"	19	2
$\frac{23}{24}$	"	"	15	33	"	18	27
$\frac{24}{25}$	"	"	15	4	"	18	2
$\frac{25}{26}$	"	"	14	22	"	16	30
$\frac{26}{27}$	"	"	14	12	"	16	3
$\frac{27}{28}$	"	"	13	55	"	17	27
$\frac{28}{29}$	"	"	12	3	"	13	22

The last was a small storm, and was followed by the greatest calm, which lasted through the whole night and following morning until noon. On the 29th to 30th Sept. 1806, at $10^{h}\ 20^{m}$ a small storm until $11^{h}\ 32^{m}$, and then great calm until $17^{h}\ 6^{m}$.

$\frac{30\text{ Sept.}}{1\text{ Oct.}}$ 1806.—At 14^h 46^m, a great storm, but of short duration ; then entire quiet ; and at 16^h 30^m another equally great storm.

The great storm of the $\frac{25}{26}$th Sept. had been preceded by a still stronger one, lasting from 7^h 8^m to 9^h 11^m. During the winter which followed, the number of disturbances was very small, and at no time to be compared with the autumnal disturbances. I give the name of "great storm" to a state in which the needle makes oscillations of from 20 to 38 minutes of arc, or passes altogether out of the scale, or moves so rapidly as to make any observation impracticable. In "small storms" the oscillations are irregular, and of from 5 to 8 minutes in amount.

([170]) p. 138.—During ten years of diligent observation at Paris, up to 1829, Arago never saw oscillations without their being accompanied by a "change of declination." He wrote to me in the above-named year: "J'ai communiqué à l'Académie les résultats de nos observations simultanées. J'ai été surpris des oscillations qu'éprouve parfois l'aiguille de déclinaison à Berlin dans les observations de 1806, 1807, et de 1828 et 1829, lors même que la déclinaison moyenne n'est pas altérée. Ici (à Paris) nous ne trouvons jamais rien de semblable. Si l'aiguille éprouve de fortes oscillations, c'est seulement en tems d'aurore boréale, et lorsque sa direction absolue a été notablement dérangée; et encore *le plus souvent* les dérangements dans la direction ne sont-ils pas accompagnés du mouvement oscillatoire." It is quite otherwise, however, with the phænomena observed at Toronto (N. lat. 43° 39′), which agree entirely with those at Berlin. The observers at Toronto were very attentive to this kind of motion, and noted "strong" and "slight vibrations," shocks, and all degrees of disturbance, according to determinate subdivisions of a definite scale, and according to a determinate and uniform nomenclature. (Sabine, Days of Unusual Magnetic Disturbances, vol. i. Pt. I. p. 46.) In this volume, comprising the observations of 1840 and 1841, an account is given in detail of six groups of successive days (amounting in all to 146 days in those two years), in which the oscillations were often very considerable ("with strong shocks"), without sensible change, from the normal declination appropriate to the hour. Such groups are designated by the heading, "Times of Observation at Toronto, at which the Magnetometers were disturbed, but the mean readings were not materially changed." (See pp. 47, 54, 74, 88, 95 and 101.) The alterations in the declination during the frequently occurring displays of aurora borealis were almost always accompanied at Toronto by strong oscillation; often such as even to make readings impossible. We learn, then, by these phænomena (the still further examination of which cannot be too earnestly recommended), that although great momentary disquiet is often followed by considerable definitive variation in the declination (Younghusband, Unusual Disturbances, Pt. II. p. x.), yet that, on the whole, the magni-

tude of the arc of oscillation is by no means generally proportioned to the magnitude of the alteration of the declination; that the oscillations may be very great, while the alteration of the declination is quite inconsiderable; and that, on the other hand, the progression of the needle in east or west declination may be rapid and considerable, without any vibratory movement; and also that these manifestations of magnetic activity may assume at different places a peculiar and different character.

([171]) p. 139.—Unusual Disturbances, vol. i. Pt. I. p. 69 and 101.

([172]) p. 139. — This was at the end of September 1806. The fact was published in Poggendorff's Annalen der Physik, Bd. xv. (April 1829) S. 330. It is there said — "My older hourly observations, made in conjunction with Oltmanns, had the advantage that at that time (1806 and 1807) no similar ones had been made either in France or in England. They gave the *nocturnal* maxima and minima [of the diurnal variation,—Ed.]; and they made known the remarkable magnetic storms, which, by the strength of the oscillatory movement of the needle, often make observation impossible, and which return for several successive nights about the same time, without its having yet been possible to discern the operation of any meteorological relations." It was not, therefore, in 1839 that a certain periodicity [*i. e.* a disposition to return at the same hours on successive nights,—Ed.] in the extraordinary disturbances was first recognised. (Report of the Fifteenth Meeting of the British Association at Cambridge, 1845, Pt. II. p. 12.)

([173]) p. 139. — Kupffer, Voyage au Mont Elbruz dans le Caucase, 1829, p. 108: " Les déviations irrégulières se répètent souvent à la même heure et pendant plusieurs jours consécutifs."

([174]) p. 140. — Sabine, Unusual Disturb., vol. i. Pt. I. p. xxi., and Younghusband, On periodical Laws in the larger Magnetic Disturbances, in the Phil. Trans. for 1853, Pt. I. p. 173.

([175]) p. 140. — Sabine, in the Phil. Trans. for 1851, Pt. I. p. 125 to 127: " The *diurnal variation* observed is, in fact, constituted by two variations *superposed* upon each other, having different laws, and bearing different proportions to each other in different parts of the globe. At tropical stations the influence of what have been hitherto called the *irregular* disturbances (*magnetic storms*) is comparatively feeble; but it is otherwise at stations situated as are Toronto (Canada) and Hobarton (Van Diemen Island), where their influence is both really and proportionally greater, and amounts to a clearly recognisable part of the whole diurnal variation." There takes place here, in the complex result of different causes acting at the same time, that which Poisson has so well described in the theory of waves (Annales de Chimie et de Physique, t. vii. 1817, p. 293):

"Plusieurs sortes d'ondes peuvent se croiser dans l'eau comme dans l'air; les petits mouvements se *superposent*." Compare Lamont's conjectures on the compound action of a polar and an equatorial wave, in Poggend. Annalen, Bd. lxxxiv. S. 583.

(176) p. 141.—See above, p. 138, Note 169.

(177) p. 142.—Sabine, in the Phil. Trans. for 1852, Pt. II. p. 110; Younghusband, in the before-quoted work, p. 169.

(178) p. 142. — According to Lamont and Relshuber, the magnetic period is $10\frac{1}{3}$ years; so that the amount of the mean diurnal movement of the needle would continually increase for five, and decrease for five years; the winter movement (or amplitude of the declination) being little more than half as great as that of the summer months. (Compare Lamont, Jahresbericht der Sternwarte zu München für 1852, S. 54—60.) The director of the Berne Observatory, Rudolph Wolf, finds, by an enquiry extending over a much longer space of time, a concurrent period of the magnetic declination and of the frequency of the solar spots of 11·1 years.

(179) p. 142.—Kosmos, Bd. iv. S. 74, 75 (Anm. 73), 77, 80, and 81 (English edition, p. 80, 81 (Note 73), 85, 88, and 89).

(180) p. 142. — Sabine, in the Phil. Trans. for 1852, Pt. I. p. 103 and 121. Compare, besides the memoir of Rud. Wolf's, already referred to (present volume, p. 81), of July 1852, and similar conjectures published, almost at the same time, by Gautier, in the Bibliothèque Universelle de Genève, t. xx. p. 189.

(181) p. 143.—Kosmos, Bd. iii. S. 401—403 (English edition, p. 291—293).

(182) p. 143.—Sabine, in the Phil. Trans. for 1850, Pt. I. p. 216. (Faraday, Exper. Researches on Electricity, 1851, p. 56, 73, and 76; § 2891, 2949, and 2958.)

183) p. 143. — Kosmos, Bd. i. S. 185 and 427, Anm. 13 (English edition, p. 168 and Note 143); Poggend. Annalen, Bd. xv. S. 334 and 335; Sabine, Unusual Disturb. vol. i. Pt. I. p. xiv—xviii., where are given tables of simultaneous storms at Toronto, Prague, and Hobarton. On days when the magnetic storms were most violent in Canada (22nd March, 10th May, 6th Aug., and 25th Sept., 1841), similar phænomena showed themselves in the southern hemisphere. Compare also Sir Edward Belcher, in the Phil. Trans. for 1843, p. 133.

(184) p. 144.—Kosmos, Bd. i. S. 219 (English edition, p. 199).

(185) p. 145.—Kosmos, Bd. i. S. 188, 189, and 430, Anm. 20—22 (English edition, p. 171 and Notes 150—152); Bd. ii. S. 319—321 and 482, Anm. 93 and 94 (English edition, p. 282 and 283, Notes 434 and 435); Bd. iv. S. 51—60 (English edition, p. 52—62).

([186]) p. 146.—At very different periods, once in 1809, in my Recueil d'Observ. astron. vol. i. p. 368, and again in 1839, in a letter to Lord Minto, then First Lord of the British Admiralty, a few days after the departure of Sir James Ross on the Antarctic Expedition, I have described more fully the importance which I attach to the proposal alluded to in the text. (Compare Report of the Committee of Physics and Meteor. of the Royal Soc. relative to the Antarctic Exped. 1840, p. 88—91.) "Suivre les traces de l'équateur magnétique ou celles des lignes sans déclinaison, c'est gouverner (diriger la route du vaisseau) de manière à couper les lignes zéro dans les intervalles les plus petits, en changeant de rumb chaque fois que les observations d'inclinaison ou de déclinaison prouvent qu'on a dévié. Je n'ignore pas que d'après de grandes vues sur les véritables fondements d'une *Théorie générale du Magnétisme terrestre*, dues à M. Gauss, la connaissance approfondie de l'*intensité horizontale*, le choix des points où les trois éléments de déclinaison, d'inclinaison et d'intensité totale ont été mesurés *simultanément*, suffisent pour trouver la valeur de $\frac{V}{R}$ (Gauss, § 4 et 27), et que ce sont là les *points vitaux* des recherches futures; mais la somme des *petites attractions* locales, les besoins du pilotage, les corrections habituelles du rumb et la sécurité des routes continuent à donner une importance spéciale à la connaissance de la position et des mouvements de translation périodique des *lignes sans déclinaison*. Je plaide ici leur cause, qui est liée aux intérêts de la géographie physique." Many years must pass away before declination-charts, constructed from the theory of terrestrial magnetism, can be such as to afford adequate guidance to navigation (Sabine, in the Phil. Trans. for 1849, Pt. II. p. 204); and the entirely objective view which I here advocate, if it led to periodically repeated determinations by sea and land expeditions undertaken for the purpose, and made, therefore, at the same time, would afford the twofold advantage of immediate practical use, and of an exact knowledge of the progressive secular movement of the lines, as well as of obtaining a large supply of fresh data as bases of calculation for the theory of terrestrial magnetism founded by Gauss (Gauss, § 25). It would be highly expedient, for the sake of the exact determination of the movement of the lines of no inclination and no declination, to establish substantial and conspicuous land-marks at the points where these lines enter or quit the coasts of continents for the years 1850, 1875, 1900. . . . . . In such expeditions, similar to the ancient ones of Halley, many other isoclinal and isogonic lines, besides those of no inclination and no declination, would be crossed and their position determined; and the horizontal and total magnetic force could also be measured (at least on shore); and thus several objects would be attained at the same time. I find the wish which I have thus

expressed supported by a great nautical authority to whom I always refer with great pleasure, Sir James Ross (Voyage in the Southern and Antarctic Regions, vol. i. p. 105).

([187]) p. 146.—Acosta, Historia de las Indias, 1590, lib. i. cap. 17. I have touched in a previous volume on the question whether, through the medium of the controversy between Boud and Beckborrow, the opinion of Dutch navigators respecting four lines of no declination may not have influenced Halley's hypothesis of four magnetic poles. (Kosmos, Bd. ii. S. 483; English edition, Note 434.)

([188]) p. 147.—In a general point of view, especial attention is due to the isogonic line of $22\frac{1}{4}°$ W. in the interior of Africa: this line connects very different systems of isogonic lines and, according to Gauss's theoretically constructed map, runs from the eastern part of the Indian Ocean across Africa and the Atlantic to Newfoundland. Perhaps the honourable extension which the British Government have given, in the present year, to the African Expedition of Richardson, Barth, and Overweg, may lead to the solution of this magnetic problem. [The particular year in which this note was written is not named. The reference is probably to the employment of Dr. Vogel, which was specially for *magnetic* determinations.—Ed.]

([189]) p. 147.—Sir James Ross crossed the line of no declination in $61\frac{1}{2}°$ S. lat. and 22° 28′ W. long. (Voyage to the Southern Seas, vol. ii. p. 357.) In 70° 43′ S. lat. and 16° 46′ W. long., in March 1843, Captain Crozier found the declination 1° 38′, and was therefore very near the line of no declination. Compare Sabine, On the Magnetic Declination in the Atlantic Ocean for 1840, in the Phil. Trans. for 1849, Pt. II. p. 233.

([190]) p. 148. — Sir James Ross, Voyage to the Southern Seas, vol. i. p. 104, 310 and 317.

([191]) p. 148.—Elliot, in the Phil. Trans. for 1851, Pt. I. p. 331, Pl. XIII. "Sandal-wood Island" is a small island on which sandal-wood (in Malay and Javanese, "tschendana;" Sanscrit, "tschandana;" Arabic, "fsandel") is obtained.

([192]) p. 149.—According to Barlow, and according to the map entitled "Lines of Magnetic Declination computed according to the Theory of M. Gauss," in the Report of the Committee for the Antarctic Expedition, 1840. According to Barlow, the line of no declination coming from Australia enters the Asiatic continent at the Gulf of Cambay and then turns again immediately north-eastward, by Thibet, China, and Formosa, to the Sea of Japan. According to Gauss, the Australian line ascends simply through Persia, by Nishnei Novgorod, to Lapland. This great geometer regards the line of no declination of the seas of Japan and the Philippines, as well as the closed oval group of isogonic lines in Eastern

Asia, as quite unconnected with the line of no declination of Australia, the Indian Sea, Western Asia, and Lapland.

([193]) p. 149.—I have spoken elsewhere (Asie Centrale, t. iii. p. 458—461) of this identity, founded on my own observations of the declination on the Caspian, at Uralsk on the Jaik River, and in the steppe near Lake Elton.

([194]) p. 149.—Adolf Erman's Map of the Magnetic Declination, 1827—1830. Elliot's Map shows decidedly that the Australian line of no declination does not traverse Java, but runs parallel to the south coast of that island, at a distance of a degree and a half of latitude to the south of it. According to Erman (not according to Gauss), the Australian line of no declination passes between Malacca and Borneo, through the Sea of Japan, to the closed oval group of Eastern Asia, entering the continent at the north shore of Ochotsk (in lat. $59\frac{1}{2}°$), and yet redescends through Malacca, so that the ascending and descending portions of the line are there only eleven degrees apart; and in this representation the west Asiatic line of no declination (from the Caspian to Russian Lapland) is an immediate continuation of the portion which comes down from north to south.

([195]) p. 150.—In 1843, in my Asie Centrale (t. iii. p. 469—476), I remarked, from documents preserved in the archives at Moscow and at Hanover, that Leibnitz (who had proposed the first plan for a French expedition to Egypt) had also been the first who had sought, by availing himself of the relations established in Germany, in 1712, with Czar Peter the Great, to get the position of the lines of declination and inclination determined throughout the Russian Empire—an extent exceeding that part of the moon's surface which is seen from the Earth—and to arrange that this determination should be repeated at given epochs. In a letter written to the Czar, which Pertz has discovered, Leibnitz refers to a small hand-globe (terrella), still preserved at Hanover, on which he had drawn the curve for which the declination is 0, his "linea magnetica primaria." He maintained that there is only one line of no declination, dividing the globe into two nearly equal parts, having four "puncta flexus contrarii," or sinuosities, running from Cape de Verde towards the American coast in 36°, and then directing itself through the Pacific towards the east of Asia and New Holland. He made this line pass not through the poles of the Earth, but nearer to the South Pole, where he supposed the declination to be 5°, than to the North, where he supposed it to be 25°. He further considered the movement of this important curve to be, in the beginning of the 18th century, towards the north; and east declination, from 0° to 15°, to prevail over great part of the Atlantic, throughout the Pacific, in Japan, and in part of China and of New Holland. He proposed that, the surgeon Donelli being dead, he should be succeeded by another, "who might give few medicines but many good scientific counsels for making the

determinations of declination and inclination." . . . . This hitherto unregarded document of Leibnitz does not manifest any particular theoretical views.

(196) p. 150.—See my magnetic observations in "Asie Centrale," t. iii. p. 400.

(197) p. 150.—Erman, Astron. und magn. Beobachtungen (Reise um die Erde, Abth. II. Bd. ii.), S. 532.

(198) p. 150.—Hansteen, in Poggend. Ann. Bd. xxi. S. 371.

(199) p. 152.—Sabine, Magn. and Meteor. Observ. at the Cape of Good Hope, vol. i. p. lx.

(200) p. 152.—In judging of such near epochs, we must not forget, in reference to this subject, how easily, with the instruments and methods then in use, an error of a degree might occur.

(201) p. 153. — Kosmos, Bd. i. S. 430, Anm. 20 (English edition, Note 150).

(202) p. 153.—Euler, in the Mém. de l'Acad. de Berlin, 1757, p. 176.

(203) p. 153.—Barlow, in the Phil. Trans. for 1833, Pt. II. p. 671. Great uncertainty prevails as to the older magnetic observations at St. Petersburg, in the first half of the 18th century. They would make the declination to have been always 3° 15′, or 3° 30′, for the whole period from 1726 to 1772! (Hansteen, Magnetismus der Erde, S. 7 and 143.)

(204) p. 154.—Kosmos, Bd. i. S. 198—210 (English edition, p. 179—189); and Dove, in Poggend. Ann. Bd. xix. S. 388.

(205) p. 154.—The meritorious examinations of Lottin, Bravais, Lilliehöök, and Siljeström, who observed the phænomena of auroras from September 19, 1838, to April 8, 1839, at Bossekop in Finnmarken (lat. 69° 58′), and at Jupvig (lat. 70° 6′), have been published in Part IV. of the "Voyages en Scandinavie, en Laponie, au Spitzberg, et aux Feroë, sur la corvette 'la Recherche' (aurores boréales)." To these observations are added important results obtained, from 1837 to 1840, by English superintendents employed in the copper mines at Kalfiord (lat. 69° 56′), p. 401—435.

(206) p. 154.—Compare p. 437—444 of the above-named work, on the subject of the "Segment obscur de l'Aurore boréale."

(207) p. 154.—Schweigger's Jahrbuch der Chimie und Physik, 1826, Bd. xvi. S. 198, and Bd. xviii. S. 364. The dark segment and the incontestable shooting upwards of black rays or streamers, in which the luminous process is nullified (? by interference), may recall to us Quet's "Recherches sur l'Electrico-chimie dans le Vide," and Ruhmkorff's fine experiments in which, in spaces containing only very rarefied air, red light streamed from the positive, and violet from the negative, metallic ball, but the intensely bright parallel strata of beams were regularly separated by wholly dark strata: "La lumière répandue entre les

boules terminales des deux conducteurs électriques se partage en tranches nombreuses et parallèles, séparées par des couches obscures alternantes, et régulièrement distinctes." (Comptes rendus de l'Acad. des Sciences, t. xxxv. 1852, p. 949.)

(208) p. 155. — Voyages en Scandinavie (aurores bor.), p. 558. On auroral coronas and canopies, see the excellent Accounts and Inquiries by Bravais, p. 502—514.

(209) p. 155.—Same work (draperie ondulante, flamme d'un navire de guerre déployée horizontalement et agitée par le vent, crochets, fragments d'arcs et de guirlandes), p. 35, 37, 45, 67, and 481. Mr. Bevalet, the distinguished artist of the expedition, has furnished an interesting collection of drawings of the various forms.

(210) p. 155. — Compare Voy. en Scand. (aur. bor.), p. 523 to 528 and 557.

(211) p. 156. — Kosmos, Bd. i. S. 201 and 441, Anm. 44 (English edition, p. 182, 183, and Note 174). Compare Franklin, Narrative of a Journey to the Shores of the Polar Sea in 1819—1822, p. 597; and Kämtz, Lehrbuch der Meteorologie, Bd. iii. (1836) S. 488—490. The oldest conjectures respecting a connection between the aurora and the formation of clouds, are probably those of Frobesius. (See Auroræ Borealis Spectacula, Helmst. 1739, p. 139.)

(212) p. 156. — I take a single example from my manuscript journal in my Siberian journey. "The night of the $\frac{5}{6}$th August (1829) was passed by me in the open air, separated from my travelling companions, at the Cossack post of Krasnaia Iarki, the most eastern one on the Irtysch, and on the boundary of Chinese Dzungarei, and therefore of some importance as regards astronomical determination of latitude and longitude. The night was extremely clear. Before midnight, there suddenly formed, on the eastern part of the heavens, polar bands of cirrus ('de petits moutons également espacés, distribués en bandes parallèles et polaires'). Greatest altitude 35°; the northern point of convergence moving slowly towards the east. They disappeared without reaching the zenith, and a few minutes afterwards similar bands of cirrus appeared on the north-eastern part of the sky. During the greater part of the remainder of the night, almost until sunrise, they again moved in a very regular manner to N. 70° E. There were an unusual number of shooting stars in the course of the night, and coloured halos round the moon. There were no traces of aurora proper. A little rain fell with feathery clouds; in the forenoon of the 6th the sky was again clear, and fresh polar bands were formed, and remained without moving or altering their azimuth, from N.N.E. to S.S.W., as I had often seen in Quito and in Mexico." (The magnetic declination is easterly.)

(213) p. 156.—Bravais, who, contrary to my experience, almost always found

the direction of the cirrus bands at Bosekop, like the auroral arch, perpendicular to the magnetic meridian (Voyage en Scandinavie; Phénomène de translation dans les pieds de l'Arc des Aurores boréales, p. 534—537), describes, with his usual exactness, the shiftings of position of the true auroral arch, p. 27, 92, 122, and 487. In the southern hemisphere, Sir James Ross also observed similar progressive changes of direction of the aurora australis, changing from W.N.W.—E.S.E. to N.N.E.—S.S.W. (Voyage in the Southern and Antarctic Regions, vol. i. p. 311.) The absence of colour seems to be very frequent in the aurora australis (vol. i. p. 266; vol. ii. p. 209). On nights without aurora in Lapland, see Bravais, work before quoted, p. 545.

(214) p. 157. — Kosmos, Bd. i. S. 440, Anm. 43 (English edition, Note 173). Auroral arches seen in daylight remind us of the strength of the light in the nuclei and tails of the comets of 1843 and 1847, which were seen in North America, at Parma, and London near the sun. Kosmos, Bd. i. S. 390, Anm. 13 (English edition, Note 43); Bd. iii. S. 563 (English edition, p. 400).

(215) p. 157.—Comptes rendus de l'Acad. des Sciences, t. iv. 1837, p. 589.

(216) p. 157. — Voyages en Scandinavie, en Laponie, &c. (aurores boréales), p. 559; and Martins, Trad. de la Météorol. de Kæmtz, p. 460. On the supposed height of the aurora, see Bravais, work above quoted, p. 549 and 559.

(217) p. 158.—Same work, p. 462.

(218) p. 158. — Sabine, Unusual Magnet. Disturbances, Pt. I. p. xviii. xxii. 3 and 54.

(219) p. 158.—Dove, in Poggend. Ann. Bd. xx. S. 333 to 341. The unequal effect exercised by an aurora on the declination needle at places situated in very different meridians, may, in many cases, lead to the determination of the place of the acting cause, for the outbreak of the luminous magnetic storm is by no means always to be sought at the magnetic pole itself; and, as Argelander had before said, and Bravais has confirmed, the summit of the luminous arch sometimes deviates more than 11° from the magnetic meridian.

(220) p. 159. — "On the 20th December, 1806. Sky azure-blue, without trace of cloud. Towards ten o'clock, there appeared in the N.N.W. a reddish-yellow luminous arch, through which I could distinguish, with the telescope, stars of the 7th magnitude; α lyræ, being almost directly under the highest point of the arch, enabled me to determine the azimuth of that point. It was situated rather to the west of the vertical plane of the magnetic declination. The aurora, which was in the N.N.W., repelled the North pole of the needle; for instead of progressing towards the west, as did the azimuth of the arch, it returned towards the east. The changes of magnetic declination, which amount

usually at night in this month to from 2′ 27″ to 3′, increased during the course of the aurora, progressively, and without any considerable oscillations, to a difference of 26′ 28″. The deflection was least at 9^h 12^m, when the auroral light was most intense. In the horizontal magnetic force, we found during the aurora $97^s{\cdot}73$ for 21 vibrations, and at 21^h 50^m — therefore long after the termination of the aurora, which had ended at 14^h 10^m — $97^s{\cdot}17$ for the same number of vibrations. The temperature of the room in which the vibrations of the small needle were observed was, in the first instance, 3°·2 Cent., and in the second, 2°·8. The intensity had therefore diminished a little during the aurora. There were no coloured rings round the moon." (Extract from my magnetic journal.) Compare Hansteen, S. 459.

([221]) p. 159.—Sabine, On Days of Unusual Magn. Disturbances, Pt. I. p. xviii. "M. Bravais conclut des observations de Laponie que l'intensité horizontale diminue pendant la période la plus active du phénomène de l'aurore boréale." (Martins, p. 461.)

([222]) p. 159.—Delesse, "Sur l'Association des Minéraux dans les Roches qui ont un pouvoir magnétique élevé," in the Comptes rendus de l'Acad. des Sc. t. xxxi. 1850, p. 806; and Annales des Mines 4e série, t. xv. (1849) p. 130.

([223]) p. 159.—Reich, on Mountain and Rock Magnetism in Poggend. Ann. Bd. lxxvii. S. 35.

([224]) p. 160.—When, in 1796, I filled the post of Superintendent of Mines in the Fichtelgebirge in Franconia, and discovered the effects of the remarkable Serpentine Mount (the Haidberg), which at some places affects the declination of needles 24 feet distant, this question was raised. (Intelligenz-Blatt der allgem. Jenaer Litteratur-Zeitung, Dec. 1796, No. 169, S. 1447, and March 1797, No. 38, S. 323—326; Gren's Neues Journal der Physik, Bd. iv. 1797, S. 136; and Annales de Chimie, t. xxii. p. 47.) I thought I had found that the magnetic axes of the mountain were directly inverted in relation to those of the Earth; but, according to the investigations of Bischoff and Goldfuss (Beschreibung des Fichtelgebirges, Bd. i. S. 196), there were indeed recognised in 1816 magnetic axes traversing the Haidberg, and presenting opposite poles at the opposite declivities, but yet the azimuthal direction of the axes differed from that which I had assigned. The Haidberg consists of green serpentine rock, partly passing into choride-slate and hornblende-slate. In South America we found at the village of Voysaco, in the Cordillera of Pasto, dykes of clay porphyry, and, in the ascent of Chimborazo, groups of columnar trachyte, which affected the needle at three feet distance. I was struck by finding in the black and red obsidians of the Quinche, north of Quito, as well as in the grey obsidian of the Cerro de las Navajas, of Mexico, large fragments having decided poles. All the con-

siderable magnetic mountains of the Oural chain, as well as that of Blagodat at Kuschwa, Wyssokaja Gora near Nishne Tagilsk, and Katschkanar at Nishne Turinsk, rise out of and have broken through augitic, or rather ouralitic porphyry. In the magnetic mountain of Blagodat, which I visited with Gustave Rose in the Siberian Expedition of 1829, it does not appear that the *general action* of the parts, which taken separately are found to have magnetic poles, has produced any determinate and recognisable *general magnetic axes*. Opposite poles lie near each other, irregularly intermingled. The same had previously been found by Erman (Reise um die Erde, Bd. i. S. 362). On the degree of strength of polar force in serpentine, basaltic, and trachytic rocks, compared to the quantity of interspersed particles of magnetic iron and oxyde of iron in these rocks, as well as on the influence of atmospheric contact in developing polarity, an influence spoken of earlier by Gmélin and Gibbs, see the numerous and very estimable observations of Zaddach, in his Beobachtungen über die magnetische Polarität des Basaltes und der trachytischen Gesteine, 1851, S. 56, 65—78 and 95. By the comparison, in respect to polarity, of many basaltic fragments of columns which had long stood exposed to the atmosphere, and of the sides of other columns for the first time exposed to its contact, and by examining other detached masses, taking away in doing so the earth which covered them, first from their upper and then from their lower portions, Dr. Zaddach thought he could infer (S. 74 and 80) that the polar property, which always appears to be most strong with free access to the atmosphere, and in rock traversed by open fissures, "spreads from the exterior towards the interior, and usually from above downwards." Gmélin said of the great magnetic mountain, Ulu-utasse-Tau, in the country of the Bashkirs, near the Jaik: "The sides which are exposed to the open air and daylight have the strongest magnetic force; those which are in the earth are much weaker." (Reise durch Sibirien, 1740—1743, Bd. iv. S. 345.) My great teacher, Werner, in his lectures on the Swedish magnetic iron, also expressed his opinion "of the influence of atmospheric contact (not acting by means of increased oxydation) in increasing polarity and attraction." In the magnetic iron mine of Succassung, in New Jersey, Colonel Gibbs states that "the ore raised from the bottom of the mine has no magnetism at first, but acquires it after it has been some time exposed to the influence of the atmosphere." (On the Connexion of Magnetism and Light, in Silliman's American Journal of Science, vol. i. 1819, p. 89.) Such a statement ought to cause exact experiments to be undertaken. In remarking in the text (p. 160) that it is not only the quantity of interspersed particles of iron in a particular kind of rock, but also their relative distribution and arrangement, which affects the strength of the resulting polar force, I considered those particles as so many small magnets. Compare

new views on this subject expressed by the great physicist Melloni, in a Memoir read by him to the Royal Academy of Naples, in January 1853. (Esperienze intorno al Magnetismo delle Rocche; Mem. I. sulla Polarità.) The old prejudice which has prevailed so extensively, particularly in the Mediterranean, that by rubbing a compass-needle with onions, or even by its being exposed to the exhalations of vinegar in which onions have been steeped, its directive force is lessened, and confusion in steering caused, is found mentioned in Procli Diadochi Paraphrasis Ptolem. libri iv. de Siderum Affectionibus, 1635, p. 30. (Delambre, Hist. de l'Astronomie ancienne, t. ii. p. 545.) It is difficult to guess what may have given occasion to this curious popular notion.

(225) p. 162.—Kosmos, Bd. iii. S. 44 (English edition, p. 35).

(226) p. 162.—Kosmos, Bd. i. S. 208—210 (English edition, p. 189—191).

(227) p. 163.—Kosmos, Bd. iii. S. 48, 431, 503, and 508—510 (English edition, p. 39, 309, 360, 365—367.)

(228) p. 164.—Kosmos, Bd. i. S. 220 (English edition, p. 200—201).

(229) p. 165. — Kosmos, Bd. i. S. 233 (English edition, p. 212). Compare Bertrand-Geslin, Sur les Roches lancées par le Volcan de Boue du Monte Zibio près du Bourg de Sassuolo, in Humboldt, Voyage aux Régions équinoxiales du Nouveau Continent (Relation historique), t. iii. p. 566.

(230) p. 165.—Robert Mallet, in the Transactions of the Royal Irish Academy, vol. xxi. (1848) p. 51—113 ; the same, First Report on the Facts of Earthquake Phenomena, in the Report of the Meeting of the British Association for the Advancement of Science, held in 1850, p. 1—89 ; the same, in the Manual of Scientific Inquiry for the Use of the British Navy, 1849, p. 196—223 ; William Hopkins, "On the Geological Theories of Elevation and Earthquakes," in the Report of the Brit. Assoc. for 1847, p. 33—92. I have availed myself in several particulars of the strict criticism to which Mr. Mallet has submitted my earlier works in his very valuable memoirs (Irish Trans. p. 99—101, and Report of Meeting of the Brit. Assoc. held at Edinburgh, p. 209).

(231) p. 165.—Thomas Young, Lectures on Natural Philosophy, 1807, vol. i. p. 717.

(232) p. 166.—I follow the statistical statement communicated to me in 1802 by the Corregidor of Tacunga. It carried the loss to the number of from 30,000 to 34,000, but some twenty years later the number of those directly killed was stated at a third less.

(233) p. 167.—Kosmos, Bd. i. S. 221 (English edition, p. 201).

(234) p. 169.—On this subject, and opposed to the supposition of molten "subjacent fluid, confined in internal *lakes*," see Hopkins, Meeting of the Brit. Assoc. in 1847, p. 57; and on "the subterraneous lava tidal wave moving the solid

crust above it," see Mallet, Meeting of Brit. Assoc. 1850, p. 20. Poisson also, with whom I more than once conversed on the hypothesis of subterranean tides caused by the moon and sun, regarded the impulse, which he did not deny, as inconsiderable, "as in the open sea the effect hardly amounts to 15 inches." On the other hand, Ampère said, " Ceux qui admettent la liquidité du noyau intérieur de la terre paraissent ne pas avoir songé assez à l'action qu'exercerait la lune sur cette énorme masse liquide, action d'où résulteraient des marées analogues à celles de nos mers, mais bien autrement terribles, tant par leur étendue que par la densité du liquide. Il est difficile de concevoir, comment l'enveloppe de la terre pourrait résister, étant incessamment battue par une espèce de bélier hydraulique (?) de 1400 lieues de longueur." (Ampère, Théorie de la Terre in the Revue des deux Mondes, juillet, 1833, p. 148.) If the interior of the Earth is fluid, as in general we cannot doubt is the case, the particles still remaining movable, notwithstanding the enormous pressure, then there will be in the interior the same conditions which, on the surface, produce the tides of the ocean, and the tide-causing force will become weaker in approaching the centre, as the difference of distance, from every two opposite points, regarded relatively to the attracting heavenly bodies, will become less the greater the depth below the surface,—and the force depends solely on the difference of the distances. If the solid crust opposes resistance, the interior will at these places only exert a pressure against the crust, but (as my astronomical friend, Dr. Brunnow, expresses it) there will be no more tide than there would be if the ocean had an icy covering which could not be burst open. The thickness of this solid unmolten crust has been calculated from the melting point of different kinds of rock, and from the increase of heat from the surface of the Earth downwards. I have already (Kosmos, Bd. i. S. 27 and 48; English edition, p. 27 and Note 13) adduced reasons in support of the conjecture that at about 20½ geographical miles below the surface the heat would attain the melting point of granite. Élie de Beaumont (Geology, edited by Vogt, 1846, vol. i. p. 32) had made the very similar estimate of 45,000 metres for the thickness of the solid crust. The ingenious experiments of Bischof on the melting of different minerals, so important to the progress of geology, would also lead to the assignment of a thickness of between 115,000 and 128,000 French feet, or a mean of about 21⅓ geographical miles, for the thickness of the unmolten strata. See Bischof, Wärmelehre des Innern unsers Erdkörpers, S. 286 and 271. I am therefore the more surprised to find that, assuming a definite limit between the solid and the molten materials (not a gradual transition), Mr. Hopkins derives from the principles of his "Speculative Geology" the result, that "the thickness of the solid shell cannot be less than about one fourth or one fifth (?) of the radius of its external surface."

(Meeting of the Brit. Assoc. held at Oxford in 1847, p. 51.) Cordier's earliest assumption had only been 56 geographical miles, without correction for the increasing pressure of the strata with increasing depth, and for the hypsometric form of the surface. The thickness of the solid portion of the Earth's crust is probably very unequal.

([235]) p. 170.—Gay-Lussac, Réflexions sur les Volcans, in the Annales de Chimie et de Physique, t. xxii. 1823, p. 418 and 426. Gay-Lussac, who, together with Leopold von Buch and myself, had observed the great eruption of Vesuvius in Sept. 1805, has the merit of having subjected the chemical hypothesis to a strict critical examination. He sought the cause of volcanic phenomena in an " affinité très-énergique et non encore satisfaite entre les substances, à laquelle un contact fortuit leur permettait d'obéir." His criticism was on the whole favourable to the hypothesis of Davy and Ampère, " en supposant que les radicaux de la silice, de l'alumine, de la chaux, et du fer soient unis au chlore dans l'intérieur de la terre:" he also deemed it not improbable that, under certain conditions, sea-water may penetrate (p. 419, 420, 423, and 426). On the difficulties of a theory which rests on the penetration of water, compare Hopkins, in the Meeting of the British Association, 1847, p. 38.

([236]) p. 170. — Hydrochloric acid is entirely wanting in the vapours emitted by the South-American volcanoes (according to the fine analyses of Boussingault at five craters, viz. those of Tolima, Purace, Pasto, Tuqueras, and Cumbal), but not in the Italian ones. (Annales de Chimie, t. lii. 1833, p. 7 and 23.)

([237]) p. 170. — Kosmos, Bd. i. S. 247 (English edition, p. 226). Davy, while most distinctly giving up the opinion that volcanic eruptions are a consequence of the contact of the metallic bases with air and water, yet stated his belief that the existence of oxydisable metalloids in the interior of the Earth might act as a *concurrent* cause in volcanic processes which had already begun.

([238]) p. 170. — " J'attribue," said Boussingault, "la plupart des tremblements de terre dans la Cordillère des Andes à des éboulements qui ont lieu dans l'intérieur de ces montagnes par l'entassement qui s'opère et qui est une conséquence de leur soulèvement. Le massif qui constitue ces cimes gigantesques n'a pas été soulevé à l'état pâteux; le soulèvement n'a eu lieu qu'après la solidification des roches. J'admets par conséquent que le relief des Andes se compose de fragments de toutes dimensions, entassés les uns sur les autres. La consolidation des fragments n'a pu être tellement stable dès le principe qu'il n'y ait des tassements après le soulèvement, qu'il n'y ait des mouvements intérieurs dans les masses fragmentaires." (Boussingault, Sur les Tremblements de Terre des Andes, in the Annales de Chimie et de Physique, t. lviii. 1835, p. 84—86.) In the description of his memorable ascent of the Chimborazo (Ascension au Chimborazo,

le 16 déc. 1831, above-quoted work, p. 176), he says again: — "Comme le Cotopaxi, l'Antisana, le Tunguragua et en général les volcans qui hérissent les plateaux des Andes, la masse du Chimborazo est formée par l'accumulation de débris trachytiques, amoncelés sans aucun ordre. Ces fragments, d'un volume souvent énorme, ont été soulevés à l'état solide par des fluides élastiques qui se sont fait jour sur les points de moindre résistance; leurs angles sont toujours tranchants." The cause of earthquakes here indicated is that which Hopkins, in his "Analytical Theory of Volcanic Phenomena," terms "a shock produced by the falling of the roof of a subterranean cavity." (Meeting of the British Assoc. at Oxford, 1847, p. 82.)

([239]) p. 171. — Mallet, Dynamics of Earthquakes, p. 74—82. All that we know of the waves of shocks and vibrations in solid bodies, shows how untenable are the older theories of the propagation of the motion being facilitated by a succession of cavities. Cavities can only act in respect to earthquakes in an indirect or secondary manner, in affording spaces for the accumulation of vapours and condensed gases. Gay-Lussac says finely: — "La terre, vieille de tant de siècles, conserve encore une force intestine, qui élève des montagnes (dans la croûte oxydée), renverse des cités et agite la masse entière. La plupart des montagnes, en sortant du sein de la terre, ont dû y laisser de vastes cavités qui sont restées vides, à moins qu'elles n'aient été remplies par l'eau (et des fluides gaseux). C'est bien à tort que Delue et beaucoup de géologues se servent de ces vides, qu'ils imaginent se prolonger en longues galeries, pour propager au loin les tremblements de terre. Ces phénomènes si grands et si terribles sont de très-fortes ondes sonores, excitées dans la masse solide de la terre par une commotion quelconque, qui s'y propage avec la même vitesse que le son s'y propagerait. Le mouvement d'une voiture sur le pavé ébranle les plus vastes édifices, et se communique à travers des masses considérables, comme dans les carrières profondes au-dessous de Paris." (Ann. de Chim. et de Phys. t. xxii. 1823, p. 428.)

([240]) p. 171. — On interference-phenomena in earthquake waves, analogous to waves of sound, see Kosmos, Bd. i. S. 211; English edition, p. 191—192, and Kleinere Schriften, Bd. i. S. 379.

([241]) p. 171.—Mallet, On Vorticose Shocks and Cases of Twisting, Meeting of Brit. Assoc. 1850, p. 33 and 49; and in the Admiralty Manual, 1849, p. 213. Compare Kosmos, Bd. i. S. 212 (English edition, p. 192.)

([242]) p. 171. — The Moya cones were seen by Boussingault nineteen years after I had seen them. "Des éruptions boueuses, suites du tremblement de terre, comme les éruptions de la Moya de Pelileo qui ont enseveli des villages entiers." (Ann. de Chimie et de Phys. t. lviii. p. 81.)

([243]) p. 173.—On the removal of buildings and plantations in the earthquake

of Calabria, see Lyell, Principles of Geology, vol. i. p. 484—491. On escape with life in fissures in the great earthquake of Riobamba, see my Relation hist. t. ii. p. 642. As a remarkable instance of the closing of a fissure, it is related by Scacchi that, in the earthquake which took place in the summer of 1851 in the Neapolitan province Basilicata, at Barile near Melfi, a hen was found caught by her two feet in the pavement of the street.

([244]) p. 174. — Kosmos, Bd. i. S. 212 (English edition, p. 192). Hopkins has shown theoretically, with great justness, how fissures produced in earthquakes may prove exceedingly instructive in reference to the formation of dykes and the phenomena of faults, inasmuch as the later formed displaces the older formation. Long, however, before the valuable labours of Phillips, Werner, in his Theory of Veins (1791), had shown the relations of precedence in age between the displacing traversing dyke and that which is displaced and traversed: compare Report of Brit. Assoc. Meeting at Oxford, 1847, p. 62.

([245]) p. 175.—On the simultaneous agitation of the tertiary calcareous strata at Cumana and Maniquarez since the great earthquake of Cumana, 14th December, 1796, compare Humboldt, Relation hist. t. i. p. 314; Kosmos, Bd. i. S. 220 (English edition, p. 200); and Mallet, Meeting of the Brit. Assoc., 1850, p. 28.

([246]) p. 175.—Abich on Daghestan, Schagdagh, and Ghilan, in Poggendorff's Ann. Bd. lxxvi. 1849, S. 157. In consequence of the wide-spreading earthquake of 29th July, 1846, the centre of commotion of which is supposed to have been about St. Goar on the Rhine, the salt-spring, in a boring at Sassendorff in Westphalia (Regier. Bezirk Arnsberg), was found, by careful analysis, to have increased its saline contents 1½ per cent., probably through the opening of fresh channels of influx (Nöggerath, das Erdbeben im Rheingebiete, vom 29. Juli, 1846, S. 14). In the Swiss earthquake of the 25th of August, 1851, Charpentier has remarked that the temperature of the sulphurous spring of Lavey (above St. Maurice on the Rhone) rose from 31° to 36°·3 cent.

([247]) p. 176. — At Schemacha,—at an elevation of 2245 French feet, one of the many meteorological stations which were established under Abich's direction by Prince Woronzow in the Caucasus,—eighteen earthquakes have been recorded by the observer in the year 1848 only.

([248]) p. 176.—See my Asie Centrale, t. i. pp. 324—329, and t. ii. pp. 108—120; and in particular my Carte des Montagnes et Volcans de l'Asie, compared with the geological maps of the Caucasus and of the highlands of Armenia, by Abich, as well as with the Map of Asia Minor, by Pierre Tschichatschef, 1853 (Rose, Reise nach dem Ural, Altai und Kasp. Meere, Bd. ii. S. 576 und 597). "Du Tourfan, situé sur la pente méridionale du Thian-chan, jusqu'à l'Archipel des

Azores, il y a 120° de longitude. C'est vraisemblablement la *bande de réactions volcaniques* la plus longue et la plus régulière, oscillant faiblement entre 38° et 40° de latitude, qui existe sur la terre ; elle surpasse de beaucoup en étendue la bande volcanique de la Cordillère des Andes dans l'Amérique méridionale. J'insiste d'autant plus sur ce singulier *alignement* d'arêtes, de soulèvements, de crevasses, et de propagations de commotions, qui comprend un tiers de la circonférence d'un *parallèle à l'équateur*, que de petits accidents de la surface, l'inégale hauteur et la largeur des rides ou soulèvements linéaires, comme l'interruption causée par les bassins des mers (concavité Aralo-Caspienne, Méditerranée et Atlantique) tendent à masquer les grands traits de la constitution géologique du globe. (Cet aperçu hasardé d'une ligne de commotion régulièrement prolongée n'exclut aucunement d'autres lignes selon lesquelles les mouvements peuvent se propager également.)" (Asie Centrale, t. ii. pp. 108. 120.) As the town of Khotan and the country south of the Thian-schan were the most celebrated and most ancient seats of Buddhism, Buddhistic literature occupied itself early and much with the causes of earthquakes. (See Foe-koue-ki, ou Relation des Royaumes Bouddhiques, trad. par Abel Rémusat, p. 217.) The adherents of Sakhyamuni assign eight such causes, among which the turning of a steel wheel hung round with relics (s'arira) plays a principal part; a mechanical explanation, scarcely more absurd than some geological and magnetical myths which were very late in becoming obsolete among ourselves. According to a note of Klaproth's, mendicant monks (Bhikchous) are imagined to have the power of making the earth tremble and setting the subterranean wheel in motion. The travels of Fahian, the author of the Foe-koue-ki belong to the beginning of the 5th century.

(249) p. 177. — Acosta, Viajes cientificos à los Andes ecuatoriales, 1849, p. 56.

(250) p. 178.—Kosmos, Bd. i. S. 214—217 and 444 (English edition, pp. 194—197 and 426), Humboldt, Rel. hist. t. iv. chap. 14, pp. 31—38. Ingenious theoretical Considerations on Waves of Sound through the Earth, and Waves of Sound through the Air, by Mallet, will be found in the Report of the Meeting of the Brit. Assoc. in 1850, pp. 41—46, and in the Admiralty Manual, 1849, pp. 201 and 217. In the tropics the animals which, according to my experience, are earlier than human beings disquieted by the slightest earthquake movements, are — poultry, swine, dogs, asses, and crocodiles (caymanes), which latter suddenly leave the bottom of the rivers.

(251) p. 179.—Julius Schmidt, in Nöggerath, on the Earthquake of the 29th of July 1846, S. 28—37. With the rate of velocity of the Lisbon earthquake as assigned in the text, the equatorial circumference of the earth would have been gone round in about 45 hours. Michell (Phil. Trans., vol. li. pt. ii. p. 572) found,

for the earthquake of the 1st of November 1755, only a rate of 50 English miles a minute (*i. e.* only 4170, instead of 7464, Paris feet in a second). There may be here partly incorrectness in the older observations, partly diversity of propagation route. — A passage of Proclus in the Commentary to Plato's Cratylus, throws a remarkable light on the connection of the sea-god Neptune with earthquakes alluded to in the text in the same page. "The middle one of the three gods, Poseidon, is the cause of motion to all, even to those things which are least movable. As the originator of motion he is called 'Εννοσίγαιος; and in casting lots for the Cronian Empire, the middle lot with the moving sea fell to his share." (Creuzer, Symbolik und Mythologie, 1842, Th. iii. S. 260.) As the Atlantis of Solon, and, as I suppose, the kindred story of Lyctonia, are "geological myths," so both these supposed fragmentary earthquake-divided lands were regarded as under the dominion of Neptune, and as such opposed to the "Saturnian continent." According to Herodotus (lib. ii. c. 43 and 50), Neptune was a Lybian divinity and unknown in Egypt. On these relations, on the disappearance of the Lybian Lake Triton by the effects of an earthquake, and the belief of the great rarity of earthquakes in the valley of the Nile, compare my Examen critique de la Géographie, t. i. pp. 171 and 179.

(252) p. 182.—The explosions of the Sangai, or Volcan de Macas, succeeded each other on an average every 13·4 seconds; Wisse, Exploration du Volcan de Sangai, in the Comptes rendus de l'Acad. des Sciences, t. xxxvi. 1853, p. 720. As an example of earthquake phenomena limited to a very small space, I might also have adduced the account given by Count Larderel of the "Lagoni" in Tuscany. The vapours, which contain borax or borassic acid, announce their presence and their being about to burst forth through fissures, by the agitation of the surrounding rocks. (Larderel, Sur les Etablissemens industriels de la production d'acide boracique en Toscane, 1852, p. 15.)

(253) p. 182.—I am glad to be able to cite an important authority in support of the view which I have attempted to unfold in the text: "Dans les Indes, l'oscillation du sol, dûe à une éruption de volcans, est pour ainsi dire locale, tandis qu'un tremblement de terre, qui, en apparence du moins, n'est lié à aucune éruption volcanique, se propage à des distances incroyables. Dans ce cas on a remarqué que les secousses suivaient de préférence la direction des chaînes de montagnes, et se sont principalement ressenties dans les terrains alpins. La fréquence des mouvemens dans le sol des Andes, et le peu de coïncidence que l'on remarque entre ces mouvemens et les éruptions volcaniques, doivent nécessairement faire présumer qu'ils sont, *dans le plus grand nombre de cas*, occasionnés par une cause *indépendante des volcans.*" (Boussingault, Annales de Chimie et de Physique, t. lviii. 1835, p. 83.)

([254]) p. 184.—The following was the order of succession of these great natural events:—

27 Sept. 1796.—Eruption of the volcano of the Island of Guadalupe after many years of repose.

Nov. 1796.—The volcano on the elevated plateau of Pasto, between the small rivers of Guaytara and Juanambu, became active, and began permanently to emit smoke.

14 Dec. 1796.—Earthquake and destruction of the town of Cumana.

4 Feb. 1797.—Earthquake and destruction of Riobamba. On the same morning, at a distance of nearly 200 geographical miles from Riobamba, the smoke from the volcano of Pasto suddenly disappeared, without any earthquake shocks being felt in its vicinity.

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30 Jan. 1811.—First appearance of the Island of Sabrina in the group of the Azores, near the Island San Miguel. The elevation of the island *preceded* the fiery eruption, as in the case of that of the Island of Santorin and the volcano of Jorullo. After six days' eruption of scoriæ, the island rose to a height of 300 feet above the surface of the sea. It was the third appearance and disappearance (by subsidence) of the island, after intervals of ninety-one and ninety-two years; always nearly at the same spot.

May 1811 to April 1812.—Above 200 earthquake shocks at the island of St. Vincent.

December 1811.—A countless number of earthquake shocks in the valleys of the Ohio, Mississippi, and Arkansas rivers, until 1813. North of Cincinnati, between New Madrid, Little Prairie, and La Saline, the earth trembled almost every hour during several months.

December 1811.—A single shock at Caracas.

26th March 1812.—Earthquake and destruction of the town of Caracas. The agitation extended beyond Santa Marta, to the town of Honda, and the elevated plateau of Bogota, 540 geographical miles from Caracas. The movement lasted until the middle of the year 1813.

30th April 1812.—Eruption of the volcano of St. Vincent; and at the same time, at two in the morning of the same day, a tremendous subterranean noise, like the loudest cannonade, was heard, in *equal intensity*, on the coasts of Caracas, in the Llanos of Calabozo, and the Rio Apure, without being accompanied by any earthquake (see p. 177 in text). The subterranean noise was also heard in the island of St. Vincent; but, which is very remarkable, stronger at some distance on the sea.

([255]) p. 186.—Humboldt, Voyage aux Régions Equinoxiales, t. ii. p. 376.

(256) p. 186.—In order to compare, in the tropics, the temperature of springs at the points where they issue directly from terrestrial strata, with the temperature of large rivers flowing in open channels, I collect here the following numbers from my journals: —

Rio Apure, lat. $7\frac{3}{4}^{\circ}$, temp. 81°.

Orinoco, between 4° and 8° lat., temp. 81°·5—85°·3.

Springs breaking forth from granite, in the forest near the cataract of Maypures, temp. 82°.

Cassiquiare, the arm of the Upper Orinoco, which forms the connection with the Amazons, temp. only 75°·8.

Rio Negro, above San Carlos, scarcely 1° 53′ north of the equator, only 74°·8.

Rio Atabapo, 79°·1.

Orinoco near the entrance of the Atabapo, lat. 3° 50′, 82°.

Rio Grande de la Magdalena, lat. 5° 12′ to 9° 56′, temp. 79°·9.

Amazons, S. lat. 5° 31′, opposite to the Pongo of Rentema (in the Provincia Jaen de Bracamoros), little more than 1200 feet above the sea, only 72°·5.

Thus it appears that the great mass of water in the Orinoco approaches the mean atmospheric temperature of the region around. When great inundations, overflowing the savannahs, take place, the yellow-brown waters, smelling of sulphuretted hydrogen, become heated up to 92°·8; I found such a temperature in the Lagartero, filled with crocodiles, east of Guayaquil. The earth becomes heated, as in shallow rivers, by the effect of the sun's rays. For the many reasons (constantly clouded skies, abundant rains, evaporation from thick forests, and absence of hot tracts of sand on the banks) of the lower temperature of the "coffee-brown waters" of the Rio Negro and the "white waters" of the Cassiquiare, see my Relat. hist. t. ii. pp. 463 and 509. In the Rio Guancabamba or Chamaya, which falls into the Amazons near the Pongo de Rentema, I have even found the temperature only 67° 6; its waters coming down with enormous rapidity, out of the high lake of Simicocha, from the Cordillera. During my fifty-two days' voyage up the Magdalena, from Mahates to Honda, I recognised clearly, by means of repeated observations, that a rise of the level of the river could be foretold, some hours previously, from the lowering of the temperature. The cooling of the water took place sooner as the source of the supply of the cold mountain-waters from the Paramos was approached. Warmth and water move, so to speak, in opposite directions, and with very unequal velocity. When the waters rose suddenly at Badillas, the temperature had previously sunk from 80°·6 to 74°·3. As passengers, sleeping at night, with their baggage, on a low

sandy island or on the shore, may be endangered by the rapid rising of the river, some importance attaches to an indication which may afford a warning. [The author then remarks that, throughout his work of the Kosmos, he always uses the Centigrade scale where the contrary is not expressly stated. In this translation, both in the present and preceding volumes, the temperatures (where nothing is expressly stated to the contrary) have always been converted from the Centigrade into Fahrenheit's scale.]

(257) p. 186. — Von Buch, Physicalische Beschreibung der Canarischen Inseln, S. 8; Poggendorff's Annalen, Bd. xii. S. 403; Bibliothèque Britannique, Sciences et Arts, t. xix. 1802, p. 263; Wahlenberg, De Veget. et Clim. in Helvetia Septentrionali observatis, p. lxxviii. and lxxxiv.; the same, Flora Carpathica, p. xciv.; and in Gilbert's Annalen, Bd. xli. S. 115; Humboldt in the Mém. de la Soc. d'Arcueil, t. iii. 1817, p. 599.

(258) p. 187. — De Gasparin in the Bibliothèque Univ., Sciences et Arts, t. xxxviii. 1828, pp. 54, 113, and 264; Mém. de la Soc. Centrale d'Agriculture, 1826, p. 178; Schouw, Tableau du Climat et de la Végétation de l'Italie, vol. i. 1839, pp. 133—195; Thurmann sur la Température des Sources de la Chaine du Jura, comparée à celle des Sources de la Plaine Suisse, des Alpes, et des Vosges, in the Annuaire Météorologique de la France pour 1850, pp. 258—268. De Gasparin divides Europe, in respect to the frequency of summer and autumn rains, into two contrasted regions. A rich collection of materials is contained in Kämtz's Lehrbuch der Meteorologie, Bd. i. S. 448—506. According to Dove (in Poggend. Ann., Bd. xxxv. S. 376), in Italy, "at places having a chain of mountains to the North, the maxima of the monthly quantities of rain fall in March and November; and where the mountains are to the South, in April and October." The totality of the relations in respect of rain in the temperate zone, as far as they can be comprised in one general view, may be stated thus: "The winter rainy season, at the borders of the tropics, divides, as we recede from them, more and more into two maxima connected by slighter falls of rain; in Germany, these two have become reunited in a summer maximum, and there remains no trace of a dry or rainless season." Compare the section "Geothermik" in the excellent "Lehrbuch der Geognosie" of Naumann, Bd. i. (1850) S. 41—73.

(259) p. 187.—Compare present volume, p. 45 (English edition, p. 45).

(260) p. 189. — Compare Kosmos, Bd. i. S. 182 and 427, Anm. 9 (English edition, p. 165 and Note 139); and present volume, p. 40 and Note 41 (English edition, p. 41 and Note 41).

(261) p. 190.—Present volume, p. 37 (English edition, p. 37).

([262]) p. 190. — Mina de Guadalupe, one of the Minas de Chota; present volume, p. 41 and 42.

([263]) p. 190. — Humboldt, Ansichten der Natur, Bd. ii. S. 323.

([264]) p. 190. — Mine on the Fleuss, in the Moll-Thal.; see Hermann and Adolph Schlagintweit, Untersuch über die physikalische Geographie der Alpen, 1850, S. 242—273.

([265]) p. 192. — The same, in their work on Monte Rosa, 1853, Cap. vi. S. 212—225.

([266] 94.—Humboldt, Kleinere Schriften, Bd. i. S. 139 and 147.

([267]) p. 194.—The same, S. 140 and 203.

([268]) p. 197.—I here depart from the opinion of a great friend, and a physicist of great merit, in respect to the terrestrial distribution of heat. See, on the cause of the hot springs of Leuck and Warmbrunn, Bischof, "Lehrbuch der chemischen und physikalischen Geologie," Bd. i. S. 127—133.

([269]) p. 197.—See, on the subject of this passage discovered by Dureau de la Malle, Kosmos, Bd. i. S. 231—232 and 448, Anm. 79 (English edition, p. 211, and Note 209). "Est autem," said St. Patricius, "et supra firmamentum cæli, et *subter* terram, ignis atque aqua; et quæ supra terram est aqua, coacta in unum, appellationem marium; quæ vero infra, abyssorum suscepit; ex quibus ad generis humani usus in terram velut siphones quidam emittuntur et scaturiunt. Ex iisdem quoque et thermæ existunt quarum quæ ab igne absunt longius, provida boni Dei erga nos mente, *frigidiores;* quæ vero *proprius* admodum, *ferventes* fluunt. In quibusdam etiam locis et tepidæ aquæ reperiuntur, prout majore ab igne intervallo sunt disjunctæ." The words are thus in the collection, "Acta Primorum Martyrum, Opera et Studio Theodorici Ruinart," ed. 2, Amstelædami, 1713, fol. p. 555. According to another account (A. S. Mazochii in Vetus Marmoreum Sanctæ Neapolitanæ Ecclesiæ Kalendarium Commentarius, vol. ii. Neap. 1744, 4to, p. 385), Patricius spoke to the following effect: "Nam quæ longius ab igne subterraneo absunt, Dei optimi providentia, frigidiores erumpunt. At quæ propiores igni sunt, ab eo fervefactæ, intolerabile calore præditæ promuntur foras. Sunt et alicubi tepidæ, quippe non parum sed longiuscule ab eo igne remotæ. Atqui ille infernus ignis impiarum est animarum carnificina; non secus ac subterraneus frigidissimus gurges, in glaciei glebas concretus, qui Tartarus nuncupatur." The Arabic name hamınâm el-Enf signifies "nose baths," and is taken, as Temple has before remarked, from the shape of a neighbouring promontory, and not from any supposed particularly favourable effects of the waters in maladies affecting the nose. The Arabic name has been variously given: hammâm l'Enf or Lif, Emmamelif (Peyssonel), la Mamelif

(Desfontaines). Compare Gumprecht, die Mineralquellen auf dem Festlande von Africa (1851), S. 140—144.

([270]) p. 198.—Humboldt, Essai Politique sur la Nouv. Espagne, 2ème ed. t. iii. (1827) p. 190.

([271]) p. 199.—Relat. hist. du Voyage aux Régions Equinoxiales, t. ii. p. 98. Kosmos, Bd. i. S. 230 (English edition, p. 208). The hot springs of Carlsbad also owe their origin to granite (Von Buch in Poggend. Ann., Bd. xii. S. 416); as do the hot springs of Momay in Thibet, visited by Joseph Hooker, which break forth 16,000 feet above the sea, with a temperature of 124°·8, near Changokhang (Himalayan Journals, vol. ii. p. 133).

([272]) p. 199.—Boussingault, Considérations sur les Eaux thermales des Cordillères, in the Annales de Chimie et de Physique, t. lii. 1833, pp. 188—190.

([273]) p. 200.—Captain Newbold, "On the Temperature of the Wells and Rivers in India and Egypt" (Phil. Trans. 1845, pt. i. p. 127).

([274]) p. 201.—Sartorius von Waltershausen, Physisch-geographische Skizze von Island, mit besonderer Rücksicht auf volkanische Erscheinungen, 1847, S. 128—132. (Physico-Geographic Sketch of Iceland, with especial regard to Volcanic Phenomena.) Bunsen and Descloiseaux, in the Comptes rendus des Séances de l'Acad. des Sciences, t. xxiii. 1846, p. 935; Bunsen, in the Annalen der Chemie und Pharmacie, Bd. lxii. 1847, S. 27—45. Lottin and Robert had already ascertained that the temperature of the column of water in the Geysir diminishes from below upwards. Among the 40 silex-containing springs, which are situated near the great Geysir and the Strokr, one bears the name of "the Little Geysir." Its column of water rises only from 20 to 30 feet. According to an account of Esoma de Körös, there is a small Geysir, sending forth a column of water about twelve feet high, in the high lands of Thibet, near the Alpine lake Mapham.

([275]) p. 201.—There are of fixed constituents, in 1000 parts in the springs of Gastein Trommsdorf only 0·303; in the Löwig, at Pfeffers, 0·291; and in the Longchamp, at Luxeuil, 0·236 : while, on the other hand, in every 1000 parts of the common spring water at Berne, there have been found 0·478 ; in the Carlsbad Sprudel, 5·459; and in the Wiesbaden water even 7·454. Studer, "Physikal. Geogr. und Geologie," 2nd edition, 1847, Cap. i. S. 92.

([276]) p. 202.—"Les eaux chaudes qui sourdent du *granite* de la cordillère du littoral (de Venezuela) sont *presque pures ;* elles ne renferment qu'une petite quantité de *silice* en dissolution, et du gaz acide hydro-sulfurique mêlé d'un peu de *gaz azote.* Leur composition est identique avec celle qui résulterait de l'action de l'eau sur le sulfure de silicium." (Annales de Chimie et de Phys. t. lii. 1833, p. 189.) On the large quantity of azote in the hot spring of Orense

(154°·4), see Maria Rubio, Tratado de las Fuentes minerales de España, 1853, p. 331.

([277]) p. 202.—Sartorius von Waltershausen, Skizze von Island, S. 125.

([278]) p. 202.—The distinguished chemist Morechini, at Rome, had given the proportion of oxygen in the waters of the spring of Nocera (2238 feet above the sea) as 0.40; Gay Lussac (26 Sept. 1805) found it more exactly only 0.299. We had previously found 0.31 in the rain water. Compare, on the nitrogen mixed with the "acid springs" of Nexis and Bourbon, l'Archambault, the older writings of Anglade and Longchamp (1834); and on carbonic acid exhalations in general, see Bischoff's excellent investigations in his "Chem. Geologie," Bd. i. S. 243—350.

([279]) p. 202. — Bunsen in Poggend. Ann., Bd. lxxxiii. S. 257; Bischoff, Geologie, Bd. i. S. 271.

([280]) p. 203.—Liebig and Bunsen, Examination of the Aix-la-Chapelle sulphurous Springs, in the Annalen der Chemie und Pharmacie, Bd. lxxix. 1851, S. 101. In chemical analyses of mineral waters containing sulphate of soda, carbonic acid, soda, and sulphuretted hydrogen are often obtained, inasmuch as there is in the same waters an excess of carbonic acid.

([281]) p. 204.—One of these cascades is drawn in my "Vues des Cordillères," Pl. xxx. On the analysis of the water of the Rio Vinagre, see Boussingault, in the Annales de Chimie et de Phys., 2e série, t. lii. 1833, p. 397; and Dumas, in the 3e série of the same, t. xviii. 1846, p. 503 ; and, on the spring in the Paramo de Ruiz, Joaquin Acosta, "Viajes cientificos a los Andes ecuatoriales," 1849, p. 89.

([282]) p. 205.—The examples of altered temperature in the thermal waters of Mariara and las Trincheras lead us to ask whether the waters of the Styx, of which the source, so difficult of access, is situated in the wild Arcadian Alps near Nonacris, in the district of Pheneos, may have lost their noxious properties by alterations which have taken place in subterranean fissures of communication? —or whether they have only sometimes proved injurious to the traveller from their icy coldness ? Possibly they may owe their evil renown, which is still handed down among the present inhabitants of Arcadia, and the myth which makes them take their rise in Tartarus, solely to the awful wildness and desert character of the surrounding scenery. A young and accomplished philologist, Theodore Schwab, succeeded a few years since, by great exertions, in reaching the rocky precipice from which the source *trickles down*, just as is indicated by Homer, Hesiod, and Herodotus. He drank of the exceedingly cold, and (judging by the taste) very pure, water without finding that he could perceive any disadvantageous effect from so doing (Schwab, Arkadien, seine Natur und Geschichte, 1852, S. 15—20). The

ancients said that the extreme coldness of the waters of the Styx burst every kind of vessel, except the hoof of an ass. Legends respecting the Styx are doubtless of primeval antiquity, but the story of the poisonous qualities of its source appears to have first become general in the time of Aristotle. According to the testimony of Antigonus of Carystus (Hist. Mirab. § 174), it was contained, very circumstantially, in a lost book of Theophrastus. The calumnious fable of the poisoning of Alexander by Styx-water, which Aristotle had caused to come into the hands of Cassander, through Antipater, is refuted by Plutarch and Arrian; it was circulated by Vitruvius, Justin, and Quintus Curtius, but without naming Aristotle. (Stahr, Aristotelia, Th. I. 1830, S. 137—140.) Pliny (xxx. 53) says somewhat equivocally "Magna Aristotelis infamia excogitatum." Compare Ernst Curtius, Peloponnesus, 1851, Bd. i. S. 194—196 and 212; St. Croix, Examen crit. des anciens Historiens d'Alexandre, p. 496. A drawing of the Fall of the Styx, taken from a distance, is given in Fiedler's Reise durch Griechenland, Th. i. S. 400.

([283]) p. 205. — "Des gîtes métallifères très-importants, les plus nombreux peut-être, paraissent s'être formés par voie de dissolution, et les filons concrétionnés n'être autre chose que d'immenses canaux, plus ou moins obstrués, parcourus autrefois par des eaux thermales incrustantes. La formation d'un grand nombre de minéraux qu'on rencontre dans ces gîtes, ne suppose pas toujours des conditions ou des agens très-éloignés des *causes actuelles*. Les deux élémens principaux des sources thermales les plus répandues, les sulfures et les carbonates alcalins, m'ont suffi pour reproduire artificiellement, par des moyens de synthèse très-simples, vingt-neuf espèces minérales distinctes, presque toutes cristallisées, appartenant aux métaux natifs (argent, cuivre et arsenic natifs); au quartz, au fer oligiste, au fer, nickel, zinc et manganèse carbonatés; au sulfate de baryte, à la pyrite, malachite, pyrite cuivreuse; au cuivre sulfuré, à l'argent rouge, arsenical et antimonial. . . . . . On se rapproche le plus possible des procédés de la nature, si l'on arrive à reproduire les minéraux dans leurs conditions d'association possible, au moyen des agens chimiques naturels les plus répandus, et en imitant les phénomènes que nous voyons encore se réaliser dans les foyers où la création minérale a concentré les restes de cette activité qu'elle déployait autrefois avec une toute autre énergie." H. de Senarmont, sur la Formation des Minéraux par la Voie humide, in the Annales de Chimie et de Physique, 3e série, t. xxxii. 1851, p. 234. (Compare also Élie de Beaumont, sur les Émanations volcaniques et métallifères, in the Bulletin de la Société Géologique de France, 2e série, t. xv. p. 129.)

([284]) p. 205. — "With the object of ascertaining the amount of difference of the mean temperature of springs from the mean atmospheric temperature Dr.

Eduard Hallmann, at his former residence at Marienberg, near Boppard, on the Rhine, observed during five years (from December 1, 1845, to November 30, 1850), the temperature of the air, the quantity of rain, and the temperature of seven different springs; and founded, on these observations, a new and revised examination of the question of the "Temperatur-Verhältnisse der Quellen." He excluded springs of thoroughly constant temperature (geological springs), including only such as undergo a variation of temperature in the course of the year. These "variable springs" fall under two natural groups: —

1) Purely meteorological springs, *i. e.*, whose mean temperature is demonstrably not heightened by terrestrial heat. In these, the amount of deviation from the mean atmospheric temperature of the place is dependent on the distribution of the fall of rain in the different seasons. Such springs are, on the mean, colder than the air, when the quantity of rain falling in the four cold months, from December to March inclusive, is more than a third of the whole quantity falling in the entire year; and they are, on the mean, warmer than the air, when the rain falling in the four warm months, July to October, exceeds one third of the whole. The negative or positive departure from the atmospheric mean is the greater, the greater the excess of rain in either the cold or the warm season. Those springs, in which the deviation from the atmospheric mean is the greatest and most accordant with the actual distribution of rain in the year, are regarded as giving "undisfigured means;" while those, in which the deviation from the atmospheric mean has been diminished by the disturbing influence of the temperature of the air when no rain falls, are classed as giving "approximate means" (both, however, coming under the general head of "purely meteorological springs"). The too near approximation of the mean to the atmospheric mean is a consequence either of the mode of obtaining the result — such as the temperature being measured at the lower end of a channel or pipe coming from the spring, — or of the spring itself having a superficial course, and of the poverty of supply. Of the Marienberg springs, four belong to the group of "purely meteorological springs," and of these four, one has an undisfigured mean, and the other three, in different degrees, approximate means. In the first observation-year, the fall of rain was in excess in the cold third of the year, and all the four springs were, in their means, colder than the air; in each of the four following years, more than a third of the year's rain fell in the warmer four months, and all the springs were, in their means, warmer than the air, and the deviation was, in each year, proportionate to the amount of the excess of warm rain.

Thus the view put forward by Von Buch in 1825, that the amount of deviation of the mean temperature of springs from the mean atmospheric temperature

must depend on the distribution of the fall of rain within the annual period, has been found perfectly correct by Hallmann, so far at least as his own station of Marienberg, in the Rhenish greywacke, is concerned. It is only "purely meteorological springs of undisfigured means" that are of value for scientific climatology; such springs ought, therefore, to be sought for everywhere for this object, in contradistinction from "purely meteorological springs of approximate means" on the one hand, and from "meteorolo-geological springs" on the other.

2) Meteorolo-geological springs are such as have temperatures demonstrably raised by the earth's heat. In these, whatever may be the distribution of the fall of rain in the year, the mean is always higher than the atmospheric mean (the variations which they show in the course of the year are imparted to them by the ground through which they flow). The amount of their excess of mean temperature over that of the air depends on the depth to which the meteoric waters sink before reappearing as a spring, and has, therefore, no climatological interest. The climatologist ought to know them, that he may not mistake them for purely meteorological springs; they may also, of course, present more or less approximation to the atmospheric mean, by reason of any channel through which their waters may be conducted to the point where their temperature is observed. The springs were observed on fixed days, four or five times a month. The height above the sea of the place of observation for atmospheric temperature, as well as that of each of the different springs, was also noted.

Dr. Hallmann, after completing and reducing his Marienberg observations, spent the winter of 1852—1853 in Italy; and found in the Apennines, besides ordinary springs, some "abnormally cold springs." He gives this name to "springs which can be shown to bring with them a lower degree of temperature from heights. They are to be regarded as subterranean outlets, either from open lakes situated high in the mountains; or from subterranean reservoirs, from which the water descends in mass, and very rapidly, through cracks and fissures, and comes out, at the foot of the hills, as a spring. The idea of an abnormally cold spring is therefore, that it is too cold for the height at which it issues forth, or rather that it issues forth at a part of the mountain too low down for its low temperature." These views, given by Dr. Hallmann in the first volume of his "Temperatur-Verhältnisse der Quellen," are somewhat modified in the second volume, S. 181—183, where he allows that all springs, even the most superficial, contain some portion of warmth derived from the earth.

([285]) p. 207.—Humboldt, Asie Centrale, t. ii. p. 58. Respecting the reasons which render it more than probable that the Caucasus, which at $\frac{5}{7}$ of its length, between Kasbegk and Elburuz, in the mean parallel of 42° 50′, runs E.S.E.—

W.N.W., is a continuation of the volcanic fissure of the Asferah (Aktagh) and Thian-schan, see the same, p. 54—61. Both these chains run, with little deviation, between the parallels of $40\frac{2}{3}°$ and 43°. The great depression of the Aral and Caspian seas, the area of which depression is estimated by Struve, from exact measurements, as exceeding that of the whole of France by almost 1680 square (German) miles (Asie Centrale, t. ii. p. 309—312), is, I think, older than the upheaval of the Altai and the Thian-schan. The fissure of elevation of the last-named chain has not extended through the great depression. It only *re*-appears west of the Caspian, as the chain of the Caucasus, with some variation of direction, but with all trachytic and volcanic phenomena. This geological connection is also recognised by Abich, and is confirmed by him by important observations. In a memoir on the connection of the Thian-schan with the Caucasus, he says, expressly:—" The frequency and decided predominance, over the whole district (between the Euxine and the Caspian), of a system of parallel lines of dislocation and upheaval (nearly from east to west), carries the mean direction of the axis of the great latitudinal Central Asiatic upheavals most decidedly to the westward of the Kosyourt and Bolor systems, and to the Caucasian isthmus. The mean direction of the Caucasus, S.E.—N.W., is, in the central portion, E.S.E.—W.N.W., and sometimes even completely E.—W., *like the Thian-schan.* The lines of elevation, or upheaval, which connect Ararat with the trachytic mountains Dzerlydagh and Kargabassar near Erzeroum, and in the southern parallels of which Argæus, Sepandagh, and Sabalan are arranged in line, are most decided indications of a mean volcanic axial direction, *i. e.* of a western prolongation of the Thian-shan through the Caucasus. Many other mountain directions of Central Asia are also met with again in this remarkable space, and these, as everywhere else, are so linked together as to form great mountain nodes, and maxima of elevation." Pliny (vi. 17) says: — " Persæ appellavere Caucasum montem Graucasim (var. Graucasum, Groucasim, Grocasum), hoc est nive candidum;" wherein Bohlen thought he recognised the Sanscrit words " käs " (to shine) and " gravan " (rock). (Compare my Asie Centrale, t. i. p. 109.) If the name Graucasus has been corrupted into Caucasus, it may, indeed, have happened, as Klausen remarks in his Investigations on the Wanderings of Io (Rheinisches Museum für Philologie, Jahrg. iii. 1845, S. 298), that a name, in which each of the first syllables recalled to the Greeks the idea of burning, may have denoted a burning mountain, with which the story of the fire-kindler, πυρκαεύς, easily connected itself poetically." It is not to be denied that myths are sometimes occasioned by names; but the origin of so great and important a myth as the Typhonian-Caucasian can scarcely be derived from the accidental similarity of sound in a misunderstood name of a mountain. There are better arguments, one of which

is referred to by Klausen. From the conjunction of Typhon and Caucasus, and from the express testimony of Pherecydes of Syros (in the fifty-eighth Olympiad) it is clear that the eastern end of the world was supposed to be a volcanic mountain. According to one of the Scholia to Apollonius (Scholia in Apoll. Rhod. ed. Schæfferi, 1813, v. 1210, p. 524), Pherecydes said in the Theogony, "that Typhon, being pursued, fled to Caucasus, and that there the mountain became on fire, and that from thence he fled to Italy, where the island of Pithecusa was thrown round him." Pithecusa is Ænaria (now Ischia), in which island Mount Epomeus (Epopon) emitted fire and lava, according to Julius Obsequens, ninety-five years before our era; again, under Titus; again, under Diocletian; and lastly, according to an exact account by Tolomeo Fiadoni of Lucca, at that time prior of Santa Maria Novella, in 1302. Böckh, who has so profound a knowledge of antiquity, said in a letter to me, "It is curious that Pherecydes should make Typhon fly from Caucasus because it was on fire, he being himself the author of the fire; but that his residence in the Caucasus was based on volcanic eruptions believed to have taken place there, seems to me also undeniable." Apollonius of Rhodes, where he speaks of the birth of the Colchian dragon (Apollon. Rhod. Argon. lib. ii. v. 1212—1217, ed. Beck.), removes to the Caucasus the "rock of Typhon," on which he was struck by the thunderbolt of Zeus. Admitting the lava-streams and crater-lakes of the highland of Kely, the eruptions of Ararat and Elburuz, and the streams of obsidian and lava from the old craters of Riotandagh, to belong to pre-historic times; yet the numerous cases of flames still breaking forth in the Caucasus, on mountains seven or eight thousand feet high, as well as from fissures in wide plains, may well have furnished ground enough for the whole Caucasian mountain-territory being regarded as a "Typhonic seat of fire."

([286]) p. 208. — Humboldt, Asie Centrale, t. ii. p. 511 and 513. I had already remarked (t. ii. p. 201) that Edrisi does not mention the fire of Baku, although 200 years before, in the tenth century, Massudi Cothbeddin had described the country at length as a "Nefala-land," *i. e.* rich in burning naphtha-springs. (Compare Frähn, Ibn Fozlan, p. 245, and On the Etymology of the Median word Naphtha, Asiat. Journal, vol. xiii. p. 124.)

([287]) p. 209. — Compare Moritz von Engelhardt and Fried. Parrot, Reise in die Krym und den Kaukasus, 1815, Th. I. S. 71, with Göbel, Reise in die Steppen des südlichen Russland's, 1838, Th. I. S. 249—253; Th. II. S. 138—144.

([288]) p. 210. — Payen, De l'Acide borique des Suffioni de la Toscane, in the Annales de Chimie et de Physique, 3e série, t. i. 1841, p. 247—255; Bischof, Chem. und physik. Geologie, Bd. i. S. 669—691; Établissements industriels de l'Acide boracique en Toscane, par le Comte de Larderel, p. 8.

(289) p. 210. — Sir Roderick Impey Murchison, On the Vents of hot Vapour in Tuscany, 1850, p. 7. (Compare also the earlier geological observations of Hoffmann in Karsten's and Decken's Archiv für Mineral. Bd. xiii. 1839, S. 19.) Targioni Tozzetti states from old, but trustworthy, traditions, that some of these springs or vents of boracic vapours were formerly seen to appear luminous at night. In order to add to the geological interest of the considerations of Murchison and Pareto, On the volcanic *serpentine Formations* in Italy, I would here refer to the circumstance that the burning flame of the Chimaera in Asia Minor (near the town of Deliktasch, the ancient Phaselis, in Lycia, on the west shore of the Gulf of Adalia), which has burnt for thousands of years, also rises from a hill on the declivity of Solimandagh, in which serpentine in sitû and blocks of limestone have been found. Rather more to the south, in the little island of Grambusa, the limestone is seen resting on dark-coloured serpentine. See the valuable Memoir of Admiral Beaufort, Survey of the Coasts of Karamania, 1818, p. 40 and 48, of which the statements have recently been entirely confirmed by the rock-specimens brought home by a very gifted artist, Albrecht Berg. (Pierre de Tchihatcheff, Asie Mineure, 1853, t. i. p. 407.)

(290) p. 210. — Bischof, work already cited, S. 682.

(291) p. 210. — Sartorius von Waltershausen, Physisch-geographische Skizze von Island, 1847, S. 123; Bunsen, "Ueber die Processe der vulkanischen Gesteinsbildungen in Island," in Poggend. Annalen, Bd. lxxxiii. S. 257.

(292) p. 210. — Waltershausen, work above cited, S. 118.

(293) p. 212. — Humboldt and Gay-Lussac, Mém. sur l'Analyse de l'Air atmosphérique, in the Journal de Physique, par Lamétherie, t. lx. an. 13, p. 151. (Compare my Kleinere Schriften, Bd. i. S. 346.)

(294) p. 213. — "C'est avec émotion que je viens de visiter un lieu que vous avez fait connaître il y a cinquante ans. L'aspect des petits volcans de Turbaco est tel que vous l'avez décrit: c'est le même luxe de la végétation, le même nombre et la même forme des cônes d'argile, la même éjection de matière liquide et boueuse; rien n'est changé si ce n'est la nature du gaz qui se dégage. J'avais avec moi, d'après les conseils de notre ami commun M. Boussingault, tout ce qu'il fallait pour l'analyse chimique des émanations gazeuses, même pour faire un mélange frigorifique dans le but de condenser la vapeur d'eau, puisqu'on m'avait exprimé le doute, qu'avec cette vapeur on avait pu confondre l'azote. Mais cet appareil n'a été aucunement nécessaire. Dès mon arrivée aux volcancitos, l'odeur prononcée de bitume m'a mis sur la voie, et j'ai commencé par allumer le gaz sur l'orifice même de chaque petit cratère. On aperçoit même aujourd'hui, à la surface du liquide qui s'élève par intermittence, une mince pellicule de pétrole. Le gaz recueilli *brule tout entier*, sans résidu d'azote (?)

et sans déposer du *soufre* (au contact de l'atmosphère). Ainsi la *nature du phénomène a complètement changé depuis votre voyage*, *à moins d'admettre une erreur d'observation*, justifiée par l'état moins avancé de la chimie expérimentale à cette époque. Je ne doute plus maintenant que la grande éruption de *Galera Zamba*, qui a éclairé le pays dans un rayon de 100 kilomètres, ne soit un *phénomène de salses* développé sur une grande échelle, puisqu'il y existe des centaines de petits cônes, vomissant de l'argile salée, sur une surface de plus de 400 lieues carrées. Je me propose d'examiner les produits gazeux des cônes de Turbarà, qui sont les salses les plus éloignées de vos volcancitos de Turbaco. D'après les manifestations si puissantes qui ont fait disparaître une partie de la péninsule de Galera Zamba, devenue une île, et après l'apparition d'une nouvelle île, soulevée du fond de la mer voisine en 1848 et disparue de nouveau, je suis porté à croire que c'est près de Galera Zamba, à l'ouest du Delta du Rio Magdalena, que se trouve le principal foyer du phénomène des salses de la province de Carthagène." (From a letter from Colonel Acosta at Turbaco to myself, 21 Dec. 1850.) Compare also Mosquera, Memoria politica sobre la Nueva Granada, 1852, p. 73; and Lionel Gisborne's Isthmus of Darien, p. 48.

([295]) p. 213. — Throughout the whole of my American expedition, I strictly followed the advice given me by Vauquelin (under whom I had worked for some time previously), to write down the details of every experiment the same day, and to preserve the record. From my journals of the 17th and 18th of April, 1801, I subjoin the following extract: — "As, according to this, the gas, when tried with phosphorous and nitrous gas, showed hardly 0·01 of oxygen, and with lime-water less than 0·02 of carbonic acid, I ask myself, what are the remaining ninety-seven parts? I first surmised carburetted and sulphuretted hydrogen; but no sulphur is deposited on the margins of the little craters, in contact with the atmosphere, nor was any smell of sulphuretted hydrogen perceived. The problematical part might seem to have been pure nitrogen, since, as above remarked, a lighted taper caused no ignition; but I know from the time when I made analyses in the Grubenwetter, that a light hydrogen gas, free from any carbonic acid, which was merely near the roof of a gallery of the mine, also did not ignite; but, on the contrary, extinguished the miners' candles, which burnt clear at points further in the interior, where there was a considerable mixture of mephitic gas. The residue of the gas of the volcancitos may, therefore, be called nitrogen with a portion of hydrogen, of which we are not yet able to state the quantity. May there be, under the volcancitos, the same carboniferous schist, which I saw to the westward at Rio Sinu, or marl, and alum? May atmospheric air penetrate through narrow cracks into cavities which have been formed by water, and, in contact with dark-gray mud, become decomposed, as in

the works in the salt-clay of Wallein and Berchtholdsgaden; where the chambers become filled with gases which extinguish burning lights? Or do elastic gases, in a state of tension, in flowing out, prevent the entrance of atmospheric air?" I wrote these questions down, fifty-three years ago, at Turbaco. According to the latest observations of M. Vauvert de Méan (1854), the inflammability of the gas exhaled has quite maintained itself. This traveller has brought back samples of the water which fills the little crater-orifices of the volcancitos. Boussingault found in a "litre" of it 6gr·59 of common salt; carbonate of soda, 0·31; sulphate of soda, 0·20; and also traces of borate of soda and iodine. In the sediment deposited, Ehrenberg, by exact microscopic examination, recognised no calcareous particles, and nothing belonging to scoriæ; but grains of quartz, mixed with laminæ of mica and many small crystalline prisms of black augite, as it often presents itself in volcanic tufa; no trace of silicified sponges or of polygastric infusoria, nothing indicating the neighbourhood of the sea; but, on the other hand, many remains of dicotyledonous plants, and of grasses, and parts of lichens, reminding us of the constituents of the Moya of Pelileo. Whereas Ch. Sainte-Claire Deville and Georg Bornemann found, in their fine analysis of the Macalube di Terrapilata, 0·99 of carburetted hydrogen in the gas emitted; the gas which rises in the Agua Santa di Limosina near Catanea gave them, as was formerly the case at Turbaco, 0·98 of nitrogen, without any trace of oxygen. (Comptes-rendus de l'Acad. des Sc. t. xliii. 1856, p. 361 and 366.)

(296) p. 214. — Humboldt, Vues des Cordillères et Monumens des Peuples indigènes de l'Amérique, Pl. XLI. p. 239. The fine drawing of the volcancitos of Turbaco, from which the plate was engraved, was by my then young travelling companion Louis de Rieux. On the ancient Tarruaco, in the earliest times of the Spanish Conquista, see Herrera, Dec. 1, p. 251.

(297) p. 215. — Lettre de M. Joaquin Acosta à M. Élie de Beaumont, in the Comtes-rendus de l'Acad. des Sc. t. xxix. 1849, p. 530—534.

(298) p. 216. — Humboldt, Asie Centrale, t. ii. p. 519—540, chiefly from extracts taken from Chinese works by Klaproth and Stanislas Julien. The old Chinese method of rope-boring, which, in the years 1830—1842, was on several occasions employed with advantage in coal-mines in Belgium and Germany, had been described (as Jobard discovered), in the seventeenth century, in the Relation de l'Ambassadeur Hollandais, Van Hoorn; but the most exact account of this method of boring the Ho-tsing (fire-wells) was given by the French missionary Imbert, who resided for many years at Kia-ting-fu. (Annales de l'Association de la Propagation de la Foi, 1829, p. 369—381.)

(299) p. 217. — According to Diard, Asie Centrale, t. ii. p. 515. Besides the mud-volcanos at Damak and Surabaya, there are also, on other islands of

the Indian Archipelago, the mud-volcanos of Pulu-Semao, Pulu-Kambing, and Pulu-Roti. (See Junghuhn, Java, seine Gestalt und Pflanzendecke, 1852, Abth. iii. S. 830.)

(300) p. 218. — Junghuhn, same work, Abth. i. S. 201; Abth. iii. S. 854—858. The weaker "Dog-grottos" in Java are Gua-Upas and Gua-Galan (the first word in these names is the Sanscrit guhä, grotto or cave). As it can scarcely be doubted that the modern "Grotta del Cane," near the Lago di Agnano, is the same that was described by Pliny (ii. cap. 93), almost eighteen centuries ago, "in agro Puteolano," as "Charonea scrobis mortiferum spiritum exhalans," we can hardly refrain from joining in the wonder expressed by Scacchi (Memorie geol. sulla Campania, 1849, p. 48), that, in a soil so loose, and so often shaken by earthquakes, a phenomenon so minute as the conduction of this small quantity of gas to its outlet, should have continued unaltered.

(301) p. 218. — Blume, Rumphia sive Commentationes botanicæ, t. i. (1835), p. 47—59.

(302) p. 219. — Humboldt, Essai géognostique sur le Gisement des Roches dans les deux Hémisphères, 1823, p. 76; Boussingault, in the Annales de Chimie et de Physique, t. lii. 1833, p. 11.

(303) p. 219. — On the height of Alausi (near Ticsan) on the Cerro Cuello see the "Nivellement baromètr." No. 206, in my Observ. astron. vol. i. p. 311.

(304) p. 220. — "L'existence d'une *source de naphte*, sortant au fond de la mer d'un micaschiste grenatifère, et répandant, selon l'expression d'un historien de la *Conquista*, Oviedo, une 'liqueur résineuse, aromatique et médicinale,' est un fait extrêmement remarquable. Toutes celles que l'on connaît jusqu'ici appartiennent aux montagnes secondaires; et ce mode de gisement semblait favoriser l'idée que tous les bitumes minéraux (Hatchett dans les *Transact. of the Linnæan Society*, 1798, p. 129) étaient dus à la destruction des matières végétales et animales ou à l'embrasement des houilles. Le phénomène du Golfe de Cariaco acquiert une nouvelle importance, si l'on se rappelle que le même terrain dit primitif renferme des feux souterrains, qu'au bord des cratères enflammés *l'odeur de pétrole* se fait sentir de temps en temps (p. e. dans l'éruption du Vésuve, 1805, lorsque le Volcan lançait des scories), et que la plupart des sources très-chaudes de l'Amérique du Sud sortent du granite (las Trincheras près de Portocabello), du gneis et du schiste micacé. Plus à l'est du méridien de Cumana, en descendant de la Sierra de Meapire, on rencontre d'abord le terrain creux (*tierra hueca*) qui, pendant les grands tremblements de terre de 1766 a jeté de l'asphalte enveloppé dans du pétrole visqueux; et puis au-delà de ce terrain une infinité de sources chaudes hydrosulfureuses." (Humboldt, Relat. hist. du Voyage aux Régions équin. t. i. p. 136, 344, 347, and 447.)

([305]) p. 223. — Kosmos, Bd. i. S. 244 (English edition, p. 223).

([306]) p. 223. — Strabo, i. p. 58. Casaub. The epithet *διάπυρος* shows that mud-volcanoes are not here spoken of. Where Plato alludes to such in his geognostical imaginations, in which he blends the mythical with the observed, he says distinctly (in opposition to the phenomenon which Strabo has described) *ὑγροῦ πηλοῦ ποταμοί.* I have already treated, on another occasion (Bd. i. S. 450—452, Anm. 95; English edition, Note 225), of the expressions *πηλός* and *ῥύαξ* as applied to volcanic outpourings. I will, therefore, only recall here another passage in Strabo (vi. p. 269), in which the hardening lava, termed *πηλὸς μέλας*, is most clearly characterised. In the description of Etna it is said: "The glowing current (*ῥύαξ*) in hardening petrifies the surface of the earth to a considerable depth, so that he who would uncover it must undertake the labour of a quarryman. For as in the crater the rock is molten, and then *uplifted*, so the fluid which streams from the summit is a black mass of mud (*πηλός*) which flows down the mountain, and after hardening becomes fit for mill-stones, and retains the colour which it had before."

([307]) p. 224. — Kosmos, Bd. i. S. 452, Anm. 98 (English edition, Note 228).

([308]) p. 224. — Leop. von Buch, Ueber basaltische Inseln und Erhebungskrater, in the Abhandl. der kön. Akademie der Wiss. zu Berlin, for 1818 and 1819, S. 51; and the same author's Physicalische Beschreibung der Canarischen Inseln, 1825, S. 213, 262, 284, 313, 323, and 341. This work, which makes an epoch in the well-based knowledge of volcanic phenomena, is the fruit of a visit to Madeira and Teneriffe, from the beginning of April to the end of October, 1815. Naumann, however, notices very properly, in his Lehrbuch der Geognosie, that in Von Buch's letters written from Auvergne in 1802 (Geognostische Beob. auf Reisen durch Deutschland und Italien, Bd. ii. S. 282), on the occasion of the description of the Mont d'Or, the theory of elevation-craters, and their essential differences from volcanoes proper, were distinctly enounced. An instructive companion-picture to the three craters of elevation in the Canaries (in the islands of Palma, Teneriffe, and the Great Canary), is presented by the Azores. The excellent maps of Captain Vidal, for the publication of which we are indebted to the British Admiralty, illustrate the wonderful geological conformation of those islands. In St. Michael we have the enormous Caldeira das sete Cidades, formed almost under the eyes of Cabral in 1444, which is an elevation-crater containing two lakes, the Lagoa Grande, and the Lagoa Azul, at a height of 866 feet. The circumference of the Caldeira de Corvo, the dry portion of whose floor is 1279 feet high, is almost as great. The elevation-craters of Fayal and Terceira are situated at almost three times this height. To the same

kind of phænomena of eruption belong the numerous but transitory insular elevations which were seen, in 1691, in the sea round the island of S. Jorge, and, in 1757, round San Miguel, for a few days only. The periodical swelling of the sea-bottom, three or four miles west of the Caldeira das sete Cidades, producing a larger island, and which was of somewhat longer duration (Sabrina), has been already noticed (Kosmos, Bd. i. S. 252; English edition, p. 230). On the elevation-crater of Astruni in the Phlegræan Fields, and "the trachytic mass pushed up in its centre as an unopened bell-shaped hill," see Leop. von Buch, in Poggendorff's Annalen, Bd. xxxvii. S. 171 and 182. Rocca Monfina (measured and drawn in Abich's Geol. Beob. über die vulkan. Erscheinungen in Unter- und Mittel-Italien, 1841, Bd. i. S. 113, Tafel II.) is a fine crater of elevation.

(309) p. 226. — Sartorius von Waltershausen, Physisch-geographische Skizze von Island, 1847, S. 107.

(310) p. 227. — It has been much debated what is the special locality in the plain of Trœzene, or the peninsula of Methana, with which we should connect the description of the Roman poet. My friend Ludwig Ross (the great investigator of Grecian antiquity by the aid of many journeys) thinks that the immediate neighbourhood of Trœzene offers no locality which can be identified with the inflated hill, and that Ovid must have transferred his graphic description to that plain by a poetic license. Ross writes: "To the south of the peninsula of Methana, and to the east of the Trœzenian plain, lies the island of Kalauria, known as the place where Demosthenes, pressed by the Macedonians, took the poison in the temple of Poseidon. A narrow strait divides the limestone of Kalauria from the coast, and gives the town and island their present name (from πόρος, a passage). In the middle of the sound, connected with Kalauria by a low, and possibly originally artificial, dike, there is a small *conical island*, in shape like an egg cut through its length. It is throughout volcanic, and consists of greyish yellow, and yellowish and reddish, trachyte, with interspersed lava and scoriæ. It is almost entirely without vegetation. The present town of Poros is built on it, on the site of the ancient Kalauria. Its formation appears quite similar to that of the more recent volcanic islands in the bay of Thera (Santorin). Ovid, in his spirited description, has probably followed a Greek model, or an ancient legend." (Ludw. Ross in a letter to myself in November 1845.) Virlet, as a member of the French scientific expedition, expressed the opinion that the volcanic elevation had been a later addition to the trachytic mass of the peninsula of Methana, and was to be found at its north-western extremity, where the black burnt rock, called kammeni-petra, quite similar to the kammeni at Santorin, betrays a later origin. Pausanias gives the tradition among the inhabitants of Methana, that, on the north coast, before the still

celebrated sulphureous thermal waters issued forth, fire had risen out of the Earth. (See Curtius, Peloponnesos, Bd. i. S. 42 and 56.) On the "indescribably sweet smell," which at Santorin (Sept. 1650) followed the sulphureous stench, see Ross, Reisen auf den Griech. Inseln des ägäischen Meeres, Bd. i. S. 196. On the smell of naphtha in the vapours from the lava of the Aleutian island of Umnack, which appeared in 1796, see Kotzebue's Entdeckungs-Reise Bd. ii. S. 106, and Leop. de Buch, Description physique des Iles Canaries, p. 458.

(311) p. 228. — The highest summit of the Pyrenees, *i. e.* the Pic de Nethou (the eastern and highest summit of the Maladetta or Malahita group), has been twice measured trigonometrically, and its height above the sea is 3481 mètres (11,420 English feet) according to Reboul, and 3404 mètres (11,168 English feet) according to Coraboeuf. It is, therefore, 1705 feet lower than Mont Pelvoux in the French Alps near Briançon. In the Pyrenees, next after the Pic de Nethou in height come the Pic Posets, or Erist, and, in the group of the Marboré, Mont Perdu and the Cylindre.

(312) p. 228.— Mémoire pour servir à la Description géologique de la France, t. ii. p. 339. Compare on Valleys of Elevation and encircling Ridges in the Silurian Formation, the excellent descriptions of Sir Roderick Murchison in his Silurian System, Pt. I. p. 427—442.

(313) p. 228. — Bravais et Martins, Observ. faites au Sommet et au Grand Plateau du Mont Blanc, in the Annuaire Météorol. de la France pour 1850, p. 131.

(314) p. 229. — Kosmos, Bd. iv. S. 221 (English edition, p. 172). I have twice visited the volcanoes of the Eifel, at very different stages of the development of modern geology: in the autumn of 1794, and in August 1845; the first time in the district of the Laacher See, and the then still inhabited Abbey; and the second time, in the district round Bertrich, the Mosenberg, and the neighbouring Maars; each time only for a few days. As, on the last excursion, I had the happiness of accompanying my intimate friend Berghauptmann von Dechen, I have been enabled, by a correspondence of many years, and by the communication of important manuscript memoirs, to avail myself freely of the observations of this clear-sighted geologist. I have often, as is my custom, distinguished, by marks of quotation, passages taken verbally from his communications.

(315) p. 230. — H. von Dechen, Geogn. Uebersicht der Umgegend von Bad Bertrich, 1847, S. 11—51.

(316) p. 230. — Stengel, in Nöggerath, Das Gebirge von Rheinland und Westphalen, Bd. i. S. 79, Tafel III. Compare also C. von Oeynhausen's excellent elucidations to his Geogn. Karte des Laacher Sees, 1847, S. 34, 39 und

42 (embracing the Eifel and the Neuwied Basin). On the Maars, see Steininger, Geognostische Beschreibung der Eifel, 1853, S. 113. His earliest, and meritorious, work, "Die erloschenen Vulkane in der Eifel und am Nieder-Rhein," belongs to 1820.

(317) p. 232. — Leucite (of the same sort as at Vesuvius, Rocca di Papa in the Alban Hills, Viterbo, Rocca Monfina, — according to Pilla sometimes more than three inches in diameter, — and in the Dolerite of Kaiserstuhl in the Breisgau) is also found "*in situ* as leucite-rock in the Eifel on the Burgberg near Rieden. The tufa in the Eifel encloses great blocks of leucitophyr near Boll and Weibern." I cannot resist the temptation of quoting from manuscript the following important remark of Mitscherlich's, contained in a chemico-geological lecture given, a few weeks ago, in the Berlin Academy: — "It is only aqueous vapours which can have caused the eruptions of the Eifel; but these would have divided the olivine and augite into the minutest drops, if they had found them still fluid. In the main mass of the ejected substances, as for example at the Dreiser Weiher, there are intermingled, in the most intimate manner, fragments of the more ancient shattered rock, and which are frequently cemented together. The great masses of olivine and the masses of augite are even, for the most part, surrounded by a thick crust of this mixture; one never finds in the olivine or in the augite any fragment of the older rock; both were, therefore, ready formed before they came to the place where the shattering took place. The olivine and augite had, therefore, already separated themselves from the fluid basaltic mass before the latter came into contact with a collection of water or a spring, which brought about an explosive ejection." Compare, respecting the bombs, an earlier memoir by Leonard Horner, in the Transactions of the Geological Soc., 2nd series, vol. iv. Pt. II. 1836, p. 467.

(318) p. 233. — Leop. von Buch, in Poggend. Annalen, Bd. xxxvii. S. 179. According to Scacchi, these ejected substances belong to the first eruption of Vesuvius of the year 79; Leonard's Neues Jahrbuch für Mineral., Jahrg. 1853, S. 259.

(319) p. 236. — On the age of formation of the valley of the Rhine, see H. von Dechen, Geogn. Beschr. des Siebengebirges, in the Verhandl. des naturhist-Vereins der Preus. Rheinlande und Westphalens, 1852, S. 556 – 559. Ehrenberg treats of the infusoria of the Eifel in the Monatsberichten der Akad. der Wiss. zu Berlin, 1844, S. 337; 1845, S. 133 and 148; 1846, S. 161—171. The Trass of Brohl, filled with morsels of pumice containing infusoria, forms hills, in some cases, more than 800 feet high.

(320) p. 236. — Compare Roset, in the Mémoires de la Société Géologique, 2e série, t. i. p. 119. Also in the island of Java, that wonderful theatre of

varied volcanic activity, "craters without cones, as it were, flat volcanoes," are found (Junghuhn, Java, seine Gestalt und Pflanzendecke, Lief. vii. S. 640) between Gunung Salak and Perwakti, "as explosion-craters," analogous to Maars. Without any encircling ridge, they are partly situated in entirely flat parts among the mountains; they have scattered around themselves angular fragments of the rocky strata which have been exploded, and they now emit only vapours and gases.

([321]) p. 237. — Humboldt, Umrisse von Vulkanen der Cordilleren von Quito und Mexico, a contribution to the Physiognomy of Nature, Plate IV. (Kleinere Schriften, Bd. i. S. 133—205.)

([322]) p. 237. — Umrisse von Vulkanen, Plate VI.

([323]) p. 237. — The same, Plate VIII. (Kleinere Schriften, Bd. i. S. 463—467. On the topographical situation of Popocatepetl ("Smoking Mountain" in the Aztec language), in reference to that of the neighbouring "White Woman" (Iztaccihuatl), and its geographical position relatively to the Lake of Tezcuco on the west, and the Pyramid of Cholula on the east, see my Atlas géogr. et phys. de la Nouvelle Espagne, Pl. III.

([324]) p. 237. — Umrisse von Vulkanen, Plate IX.; the Star-Mount, in Aztec language Cittaltepetl; Kleinere Schriften, Bd. i. S. 467—470, and my Atlas géogr. et phys. de la Nouv. Espagne, Pl. XVII.

([325]) p. 237. — Umrisse von Vulk. Pl. II.

([326]) p. 237. — Humboldt, Vues des Cordillères et Monuments des Peuples indigènes de l'Amérique (fol.), Pl. LXII.

([327]) p. 237. — Umrisse von Vulk. Pl. I. and X. Kleinere Schriften, Bd. i. S. 1—99.

([328]) p. 238. — Umrisse von Vulk. Pl. IV.

([329]) p. 238. — The same, Pl. III. and VII.

([330]) p. 238. — Long before the arrival of Bouguer and La Condamine (in 1736) in the high plain of Quito, long, therefore, before scientific measurements of the heights of mountains, the natives knew that Chimborazo exceeded in height all the other snow-clad mountains of the region. They had recognised two lines of level which remain nearly constant throughout the year: one, the the lower line of *perpetual* snow; and the other, the line to which a single casual fall of snow descends. Inasmuch as in the equatorial region of Quito, as I have elsewhere shown by measurements (Asie centrale, t. iii. p. 255), the snow-line, on six of the highest of these mountain-giants, only varies about 200 feet; and as this variation, as well as the lesser ones produced by local circumstances, is scarcely perceptible to the naked eye at so great a distance (the height of the snow-line under the equator is equal to the height of Mont Blanc), the result is

an apparently perfect regularity and uninterrupted horizontality, which astonish the observer accustomed to all the irregularity in the extent of the snowy covering which belongs to our variable temperate zone. This uniformity in the height of the snow-line, and the knowledge of its maximum variation, in the region round Quito, furnish an observer with *vertical* base-lines of 15,800 English feet above the sea, and 6400 above the high plain; of which, combined with very exact measurements of angles of altitude, he can avail himself in the determination of distances, and the rapid solution of other topographical questions. The second of the level lines above spoken of, *i. e.* the horizontal line which marks the lowest limit to which the snow of a single casual fall descends, decides as to the relative height of lower mountains, whose summits do not enter the region of perpetual snow. Of a long chain of such summits, which had been erroneously regarded as of equal elevation, many are seen to remain below the temporary fall of snow while the rest are above it; and thus the estimation as to their relative height is corrected. In the mountain region of Quito, where the Sierras Nevadas often approach each other, but without their perpetual snow-coverings being continuously connected, I have often heard, from the lips of uneducated country people and herdsmen, such considerations and inferences from the lines of perpetual snow and of casual snow showers. The grandeur of nature stimulates the intellectual susceptibility of individuals among the coloured inhabitants, even where they are in the lowest stage of civilisation.

(331) p. 239. — Abich, in the Bulletin de la Société de Géographie, 4e série, t. i. (1851) p. 517; with a fine representation of the form of the ancient volcano.

(332) p. 239. — Humboldt, Vues des Cord. p. 295, Pl. LXI., and Atlas de la Relat. hist. du Voyage, Pl. XXVII.

(333) p. 240. — Kleinere Schriften, Bd. i. S. 61, 81, 83 and 88.

(334) p. 241. — Junghuhn, Reise durch Java, 1845, S. 215, Tafel XX.

(335) p. 241. — See Adolf Erman's Reise um die Erde (a work of great geological importance, as well as valuable in so many other ways), Bd. iii. S. 271 and 207.

(336) p. 241. — Sartorius von Waltershausen, Physisch-geographische Skizze von Island, 1847, S. 107; and his Geognostischer Atlas von Island, 1853, Taf. XV. and XVI.

(337) p. 242. — Otto von Kotzebue, Entdeckungs-Reise in die Südsee und in die Berings-Strasse, 1815—1818, Bd. iii. S. 68; Reise-Atlas by Choris, 1820, Taf. V.; Vicomte d'Archiac, Hist. des Progrès de la Géologie, 1847, t. i. p. 544; and Buzeta, Diccionario geogr. estad. historico de las Islas Filipinas, t. ii. (Madr. 1851), p. 436 and 470—471: where, however, there is no mention of the double circle (of a second

crater in the crater-lake) which Delamare has described so circumstantially and with so much scientific exactness in his letter to Arago (Nov. 1842, Comptes rendus de l'Acad. des Sc. t. xvi. p. 756). The great eruption in Dec. 1754 (an earlier and more violent one had taken place in September 1716) destroyed the old village of Taal, situated on the south-western shores of the lake, and which has been subsequently rebuilt further from the volcano. The small island in the lake, on which the volcano rises, is called Isla del Volcan (Buzeta's work above referred to). The absolute height of the volcano of Taal is about 890 feet. It is, therefore, like Kosima, one of the very lowest. At the time of the American expedition under Captain Wilkes (1842), it was in full activity. See United States Explor. Exped. vol. v. p. 317.

(338) p. 242. — Humboldt, Examen crit. de l'Hist. de la Géogr. t. iii. p. 135; Hannonis Periplus in Hudson's Geogr. Græci Min. t. i. p. 45.

(339) p. 242. — Kosmos, Bd. i. S. 238 (English edition, p. 217).

(340) p. 244. — For the situation of this volcano, which in smallness is only exceeded by the volcanoes of Tanna and of the Mendaña, see the fine Map of the Japanese Empire by F. von Siebold, 1840.

(341) p. 244. — I do not here name, with the Peak of Teneriffe, among island volcanoes, Mauna-roa, to whose conical form its name does not correspond; for in the Sandwich island language Mauna signifies mount, and roa signifies long and very. Nor do I name Hawaii, the height of which was long debated, and which was long described as an unopened trachytic dome. The celebrated crater of Kiraueah, a lake of molten lava, situated to the east of Mauna-roa, near its foot, is 3969 feet high according to Wilkes. Compare the excellent description in Charles Wilkes's Exploring Expedition, vol. iv. p. 165—196.

(342) p. 245. — Letter from Fr. Hoffmann to Leop. von Buch, On the geological Constitution of the Lipari Islands, in Poggend. Annalen, Bd. xxvi. 1832, S. 59. Volcano, 1268 feet high according to the recent measurement of Ch. Sainte Claire Deville, had strong eruptions of scoriæ and ashes in 1444, at the end of the sixteenth century, in 1731, in 1739, and in 1771. Its fumaroles contain ammonia, borate of selenium, sulphuret of arsenic, phosphorus, and, according to Bornemann, traces of iodine. The three last-named substances are here found for the first time among volcanic products. (Comptes Rendus de l'Acad. des Sc. t. xliii. 1856, p. 683.)

(343) p. 245. — Squier, in the American Association (tenth annual meeting, at New Haven, 1850).

(344) p. 245. — See Franz Junghuhn's highly instructive work, Java, seine Gestalt und Pflanzendecke, 1852, Bd. i. S. 99. Ringgit is now almost extinct; many thousand human beings perished in its terrible eruptions in 1586.

(345) p. 245. — Thus the summit of Vesuvius is only 258 feet higher than the Brocken.

(346) p. 245. — Humboldt, Vues des Cordillères, Pl. XLIII.; and Atlas géogr. et phys. Pl. XXIX.

(347) p. 246. — Junghuhn, work above quoted, Bd. i. S. 68 and 98.

(348) p. 246. — Compare my Relat. hist. t. i. p. 93, particularly in respect to the distance at which the summit of the volcano of the island Pico has sometimes been seen. The older measurement of Ferrer gave 7916 feet, therefore 304 feet more than the certainly more careful survey of Vidal in 1843.

(349) p. 246. — Erman, in his interesting geological description of the volcanoes of the peninsula of Kamtschatka, gives to Awatschinskaia or Gorelaia Sopka 8910 feet; and to Strieloschnaia Sopka, also called Koriurkaia Sopka, 11,819 feet. (Reise, Bd. iii. S. 494 and 540.) Compare, respecting these two volcanoes, of which the first is the most active, L. de Buch, Descr. phys. des Iles Canaries, p. 447—450. Erman's measurement of the volcano of Awatscha agrees most nearly with the earliest measurement by Mongez, in 1787, in the expedition of La Perouse (8757 feet), and with the more recent one of Beechey (9056 feet). Hofmann in Kotzebue's, and Lenz in Lütke's, Voyages, found only 8168 and 8212 feet. Compare Lütke, Voy. autour du Monde, t. iii. p. 67—84. Lütke's measurement of the Strieloschnaia Sopka gave 11,199 feet.

(350) p. 246. — Compare Pentland's table of heights in Mary Somerville's Phys. Geogr. vol. ii. p. 452; Sir Woodbine Parish, Buenos-Ayres and the Prov. of the Rio de la Plata, 1852, p. 343; Pöppig, Reise in Chile and Peru, Bd. i. S. 411–434.

(351) p. 246. — May the summit of this remarkable volcano be diminishing in height? A barometric measurement by Baldey, Vidal, and Mudge, in 1819, still gave 9758 feet; whereas a very accurate and practised observer, who has rendered important services to the geology of volcanoes, Sainte Claire Deville (Voyage aux Iles Antilles et à l'Ile de Fogo, p. 125), found, in 1842, only 9152 feet. Captain King, a short time before, had even found only 8810 feet.

(352) p. 247. — Erman, Reise, Bd. iii. S. 271, 275, and 297. The volcano Schiwelutsch has, like Pichincha, the form, rare among active volcanoes, of a long ridge (chrebet), on which rise detached domes and crests (grebni). Conical and bell-shaped mountains are always designated, in the volcanic district of the peninsula, by the term sopki.

(353) p. 247. — On the remarkable agreement of the trigonometric measurement with the barometric one of Sir John Herschel, see Kosmos, Bd. i. S. 41, Anm. 2 (English edition, Note 2).

(354) p. 247. — The barometric measurement of Sainte Claire Deville (Voy.

aux Antilles, p. 102—118), in 1842, gave 12,158 feet, nearly accordant with the result (12,181 feet) of the second trigonometric measurement of Borda in 1776, which I was enabled to publish from the Manuscrit du Dépôt de la Marine. (Humboldt, Voy. aux Régions équinox. t. i. p. 116 and 275—287.) Borda's first trigonometric measurement, executed jointly with Pingré in 1771, gave, instead of 12,181 feet, only 11,139 feet. The cause of the error was in the erroneous notation of an angle (33′ instead of 53′), as was related to me by Borda himself, to whose great personal kindness I was indebted for so much useful advice before my voyage to the Orinoco.

([355]) p. 247. — I follow Pentland's statement of 12,367 feet; the more so because Sir James Ross (Voy. of Discovery in the Antarctic Regions, vol. i. p. 216) gave, as an approximate result, 12,400 feet as the height of this volcano, of which the smoke and flames were visible even in the daytime.

([356]) p. 247. — On Mount Argæus, which was first ascended and barometrically measured (at 12,705 feet) by Hamilton, see Pierre de Tchihatcheff, Asie Mineure (1853), t. i. p. 441—449 and 571. William J. Hamilton, in his excellent work (Researches in Asia Minor), obtained, as a mean result from a barometric measurement and some angles, 13,000 feet; but if, as according to Ainsworth, the height of Kaisarich is 1000 feet less than it was assumed by Hamilton, it is only 12,000 feet. Compare Hamilton, in the Transact. of the Geol. Soc. vol. v. Pt. III. 1840, p. 596. To the south-east of Argæus (Erdschisch-Dagh), in the great plain of Eregli, south of the village of Karabunar and of the mountain-group of Karadsha-Dagh, there rise several very small cones of eruption. One of these, provided with a crater, has a form wonderfully resembling that of a ship, running out in front into the shape of a prow. This crater is in a salt lake, on the way from Karabunar to Eregli, fully four miles from the former. The hill bears the same name. (Tchihatcheff, t. i. p. 455; William J. Hamilton, Researches in Asia Minor, vol. ii. p. 217.)

([357]) p. 247. — The height given is, properly speaking, that of the grass-green mountain lake, the Laguna Verde, on the margin of which the Solfatara examined by Boussingault is found. (Acosta, Viajes cientificos á los Andes ecuatoriales, 1849, p. 75.)

([358]) p. 247. — Boussingault reached the crater, and measured the height barometrically; it agrees very nearly with that which I stated by estimation, twenty-three years earlier, on my journey from Popayan to Quito.

([359]) p. 247. — Few volcanoes have had their height so over-estimated as Mauna-roa. We have seen its supposed height gradually diminish from 18,400 feet (stated in Captain Cook's third voyage) to 16,482 feet in King's, and 16,613 feet in Marchand's measurement, to 13,758 feet according to Wilkes,

and 13,528 according to Horner in Kotzebue's Voyage. The data, on which the last-named result is based, were first published, by Von Buch, in the Descr. phys. des Iles Canaries, p. 379. Compare Wilkes, Explor. Exped. vol. iv. p. 111—162. The eastern margin of the crater is only 13,428 feet. Mauna-roa being stated to be without snow (lat. 19° 28′), the assumption of a greater height would be in opposition to the result found by me in Mexico by many measurements, giving, for the lower limit of perpetual snow, in the same latitude 14,470 feet. (Humboldt, Voy. aux Rég. équinox. t. i. p. 97; Asie Centr. t. iii. p. 269 and 359.)

([360]) p. 247.— This volcano rises to the west of the village of Cumbal, which is itself 10,563 feet above the sea. (Acosta, p. 76.)

([361]) p. 247. — I give the result of Erman's repeated measurements in Sept. 1829. The height of the margin crater must be subject to alterations from the effects of the numerous eruptions; for measurements, equally carefully taken in Aug. 1828, had given 16,029 feet. Compare Erman's Physikalische Beobachtungen auf einer Reise um die Erde, Bd. i. S. 400 and 419, with the "Historischen Bericht" of the Travels, Bd. iii. S. 358—360.

([362]) p. 247. — Bouguer and La Condamine, in the Inscription at Quito, give for Tungurahua before the great eruption of 1772, and before the earthquake of Riobamba (1797), which caused great mountain-falls, 16,773 feet: I found trigonometrically, in 1802, only 16,490 for the summit of the volcano.

([363]) p. 248. — The barometric measurement of the highest summit of the Volcan de Puracé, by Francisco José Caldas (who, like my dear friend and travelling companion Carlos Montufar, fell a sacrifice to his love for the independence and freedom of his native land), is given by Acosta (Viajes cientificos, p. 70) at 17,006 feet. For the little crater (Azufral del Boqueron), from which sulphureous vapours issue with a violent noise, I found 14,414 feet. (Humboldt, Recueil d'Observ. astron. et d'Opérations trigon. vol. i. p. 304.)

([364]) p. 248. — Sangay is exceedingly remarkable for its uninterrupted activity, and for its situation: being somewhat to the east of the eastern Cordillera of Quito, south of the Rio Pastaza, and 104 geographical miles from the nearest part of the coast; therefore (like the volcanoes of the "Celestial Mountains" in Asia) far from lending any support to the theories which say that the eastern Cordilleras of Chili are free from volcanic eruptions by reason of their distance from the sea. Darwin did not fail to remark, in some detail, on the subject of this old and widely diffused coast-theory, in his Geological Observations on South America, 1846, p. 185.

([365]) p. 248. — I measured the height of Popocatepetl, also called the Volcan Grande of Mexico, in the plain of Tetimba, near the Indian village San Nicolas

de los Ranchos. It still appears to me uncertain which of the two volcanoes, Popocatepetl or the Peak of Orizaba, is the highest. Compare Humboldt, Recueil d'Observ. astron. vol. ii. p. 543.

(366) p. 248. — The Peak of Orizaba, covered with perpetual snow, of which, previously to my journey the geographical position was given extremely erroneously upon all maps and charts notwithstanding its great nautical importance to vessels coming to Vera Cruz, was first measured trigonometrically, in 1796, by Ferrer from Encero. The result was 17,879 feet. I tried a similar operation in a little plain near Xalapa, and found only 17,374 feet; but the angles of altitude were very small, and the base was difficult to level. Compare Humboldt, Essai Politique sur la Nouv. Espagne, 2e éd. t. i. 1825, p. 166; my Atlas du Mexique (carte des fausses positions), Pl. X.; and Kleinere Schriften, Bd. i. S. 468.

(367) p. 248. — Humboldt, Essai sur la Géogr. des Plantes, 1807, p. 153. The height is uncertain, perhaps more than $\frac{1}{15}$th too great.

(368) p. 248. — I measured, in 1802, the height of the truncated cone of the volcano of Tolima, situated at the northern end of the Paramo de Quindiu, in the Valle del Carvajal, near the little town of Ibague. The mountain is also seen, at a great distance, from the high plain of Bogota. At this distance, Caldas, in 1806, by a somewhat complicated combination, obtained a tolerably approximate result, 18,430 feet; Semanario de la Nueva Granada, nueva edicion, aumentada por J. Acosta, 1849, p. 349.

(369) p. 248. — The absolute height of the volcano of Arequipa has been so variously given, that it is difficult to distinguish between mere estimations and actual measurements. The distinguished botanist of Malaspina's Voyage of Circumnavigation, Dr. Thaddæus Hänke, of Prague, ascended it in 1796, and found on the summit a cross, which had been erected there twelve years before. By a trigonometrical operation, Hänke is said to have found, for the height of the volcano above the sea, 20,335 English feet (19,080 Paris feet). This result, for the absolute height, is much too great, and may perhaps have arisen from an erroneous assumption of the absolute height of the town of Arequipa, in the neighbourhood of which the operation was executed. If Hänke had then been provided with a barometer, surely, after having been on the summit, he, as a botanist, unaccustomed to trigonometrical operations, would not have resorted to them. The next person who ascended the volcano, was Samuel Curzon, of the United States. (Boston Philosophical Journal, 1823, Nov. p. 168.) In 1830, Pentland estimated it at 18,373 feet, and I have used this number (Annuaire du Bureau des Longitudes pour l'an 1830, p. 325) for my Carte hypsométrique de la Cordillère des Andes, 1831. It agrees pretty well (to almost $\frac{1}{47}$) with the trigonometric measure-

ment by a French naval officer, M. Dolley, kindly communicated to me in Paris by Capitaine Alphonse de Moges, in 1826. Dolley found the summit of Arequipa 10,928 feet, and that of Charcani 11,857 feet above the high plain in which the town of Arequipa is situated. Taking the height of the town at 7850 feet, from the barometric measurements of Pentland and Rivero (Pentland gives 7852 feet in his table of heights, in the third edition of Mary Somerville's Physical Geography, 3rd. ed. vol. ii. p. 454; and see Rivero, in the Memorial de Ciencias naturales, t. ii. Lima, 1828, p. 65; Meyen, Reise um die Erde, Th. II. 1835, S. 5), we obtain, from Dolley's trigonometric operation, for the volcano of Arequipa 18,876 feet, and for that of the volcano of Charcani 19,708 feet. But the above-cited table of altitudes of Pentland gives for the volcano of Arequipa 20,320 feet (19,065 Paris feet), which is more than 2000 feet above Pentland's estimate in 1830, and only too identical with Hänke's result in 1796, which was 19,080 Paris feet! On the other hand, in the Anales de la Universidad de Chile, 1852, p. 221, the same volcano is given so low as 18,373 feet! A melancholy state of hypsometrical information!

([370]) p. 248. — Boussingault, accompanied by a highly informed companion, Colonel Hall, almost reached the summit of Cotopaxi. They arrived, according to barometric measurement, at a height of 18,862 feet. There remained only a short distance to the margin of the crater, but the exceeding looseness of the snow forbade further progress. Perhaps Bouguer's result may have been rather too small, as his complicated trigonometric computation is dependent on the height of the town of Quito.

([371]) p. 248. — Sahama, which Pentland (Annuaire du Bureau des Longitudes pour 1830, p. 321) distinctly affirms to be a still active volcano, is situated, according to his new map of the valley of Titicaca (1848), east of Arica, in the western Cordillera. It is 928 feet higher than Chimborazo; and the proportion of its height to that of the lowest Japanese volcano Kosima, is as 30 to 1. I have abstained from placing in the fifth group the Chilian Acongagua, which, according to its latest measurement, by Captain Kellett in the Herald in 1845, is 23,004 feet high, because from the opposite opinions of Miers (Voyage in Chili, vol. i. p. 283) and Charles Darwin (Journal of Researches into the Geology and Natural History of the different Countries visited by the Beagle, 2nd ed. p. 291) it remains somewhat doubtful whether this colossal mountain is a still active volcano. Mary Somerville, Pentland, and Gillies (Naval Astron. Exped. vol. i. p. 127) deny its being so. Darwin says: "I was surprised at hearing that Acongagua was in action the same night (15th Jan. 1835), because this mountain most rarely shows any signs of action."

([372]) p. 249. — These breaking-through masses of porphyry show themselves on a great scale near the Illimani in Cenipampa (15,946 feet) and Totoropampa (13,705 feet). A quartz-porphyry, containing mica and enclosing garnets and angular fragments of siliceous schist, forms the summit of the celebrated argentiferous Cerro de Potosi. (Pentland, in MSS. of 1832.) The Illimani, to which Pentland gave first a height of 7315, and afterwards of 6445 mètres, has been carefully measured, since 1847, by the engineer Pissis, who, on the occasion of his great trigonometrical survey of the Llanura de Bolivia, found, by three triangles between Calamarca and La Paz 6509 mètres, 21,355 English feet, differing only 64 mètres from Pentland's latest determination. See Investigaciones sobre la Altitud de los Andes, in the Anales de Chile, 1852, p. 217 and 221.

([373]) p. 250.— Sartorius von Waltershausen, Geogr. Skizze von Island, S. 103 and 107.

([374]) p. 251. — Strabo, lib. vi. p. 276, Casaub.; Plin. Hist. Nat. iii. 9: "Strongyle, quæ a Lipara liquidiore flamma tantum differt; et cujus fumo quinam flaturi sint venti, in triduo prædicere incolæ traduntur." Compare also Urlich's Vindiciæ Plinianæ, 1853, fasc. i. p. 39. The once so active volcano of Lipara (in the north-east of the island) appears to me to have been either the Monte Campo Bianco, or the Monte di Capo Castagno. (Compare Hoffmann, in Poggend. Annalen, Bd. xxvi. S. 49—54.)

([375]) p. 252. — Kosmos, Bd. i. S. 231 and 448, Anm. 77 (English edition, vol. i. p. 210 and Note 207). Albert Berg, who had previously published a picturesque work, Physiognomie der tropischen Vegetation von Südamerika, in 1853 went from Rhodes and the Bay of Myra (Andriace) to visit the Chimæra in Lycia, near Deliktasch and Yanartasch. (The Turkish word täsch, signifies rock, as dâgh and tâgh do mountain; Deliktasch is "perforated rock," from the Turkish delik, a hole.) This traveller first saw the serpentine rock at Adrasan. Beaufort had already seen, in the island of Garabusa (not Grambusa) south of Cape Chelidonia, the dark serpentine rock resting on limestone (perhaps imbedded in it). I subjoin an extract from a MS. communication from Albert Berg: — "Near the ruins of an ancient temple of Vulcan rise the remains of a Christian church in the late Byzantine style; remains of a nave and of two side chapels. In a fore-court to the east, the flame comes forth in an opening like that of a fire-place, about two feet broad, and one foot high, in the serpentine-rock. It rises about three or four feet high, and gives out a sweet smell, perceptible at a distance of forty paces." (Is this a naphtha spring?) "Besides this great flame, and beyond the hearth-like orifice, there also appear, on side-clefts, very small, but constant, tongues of flame. The rock, where it is touched by the flame, is much blackened; and the soot deposited is collected for

application to the eyelids, both to relieve pain, and particularly for colouring the eyebrows. At three paces from the Chimæra, the warmth from it is difficult to bear. A stick of dry wood held in the opening near the flame, but without touching it, takes fire. Where the ancient walls lean against the rock, gas escapes from the interstices between the stones, which, probably because either the temperature is lower, or the mixture is somewhat different, does not ignite spontaneously, but burns when lighted. Eight feet below the large flame, in the interior of the ruins, there is an opening, six feet deep, but only half as wide, which probably was once vaulted over, for, in the damp part of the year, a spring of water breaks out in it by the side of a cleft, over which a little flame plays." Berg shows, on a topographical plan, the geographical relations of the alluvial strata, of the (tertiary?) limestone, and of the serpentine-rock.

(376) p. 253. — The oldest and most important notice on the volcano of Masaya is in a manuscript, edited fourteen years ago by the meritorious historical collector Ternaux-Compans, of Oviedo's Historia de Nicaragua (cap. v. to x.); see p. 115—197. The French translation forms a volume of the Voyages, Relations, et Mémoires originaux pour servir à l'Histoire et à la Découverte de l'Amérique. Compare also Lopez de Gomara, Historia general de las Indias (Zaragoza, 1553), fol. cx. b; and, among very recent writings, Squier, Nicaragua, its People, Scenery, and Monuments, 1853, vol. i. p. 211—223, and vol. ii. p. 17. The volcano of Masaya was then so celebrated that, in the Royal Library at Madrid, there is a monograph upon it entitled: Entrada y Descubrimiento del Volcan de Masaya que está en la Prov. de Nicaragua, fecha por Juan Sanchez del Portero. The author was one of those who let themselves down into the crater in the strange attempts of the Dominican Fray Blas de Iñesta. (Oviedo, Hist. de Nicaragua, p. 141.)

(377) p. 254. — In the French translation of Ternaux-Compans (the Spanish original has not been published), it is said, p. 123 and 132: — "On ne peut cependant dire qu'il sorte précisement une flamme du cratère, mais bien une fumée aussi ardente que du feu; on ne la voit pas de loin pendant le jour, mais bien de nuit. Le volcan éclaire autant que le fait la lune quelques jours avant d'être dans son plein." This remark, made so long ago on the kind of illumination of a crater, and of the strata of air over it, is not without bearing on the doubts which have of late often been raised as to the disengagement of hydrogen gas from the craters of volcanoes. If, in its ordinary state, here alluded to, El Infierno de Masaya did not erupt scoriæ or ashes (Gomara adds: cosa que hazen otros volcanes), yet it has sometimes had real eruptions of lava, of which probably the latest was in 1670. Since then the volcano has become completely extinct, after a perpetual light from it having been observed for 140 years.

Stephens, who ascended it in 1840, found no sensible trace of ignition. On the Chorotega language, the meaning of the word Masaya, and the Maribios, see Buschmann's ingenious ethnographic investigations Ueber die aztekischen Ortsnamen, S. 130, 140, and 171.

(378) p. 255.—"Les trois compagnons convinrent de dire qu'ils avaient trouvé de grandes richesses; et Fray Blas, que j'ai connu comme un homme ambitieux, rapporte dans sa relation le serment que lui et les associés firent sur l'évangile, de persister à jamais dans leur opinion que le volcan contient de l'or mêlé d'argent en fusion." Oviedo, Descr. de Nicaragua, cap. x. p. 186 and 196. The chronicler de las Indias is very angry at Fray Blas having said that "Oviedo had begged the emperor to give him El Infierno de Masaya in his coat of arms." This would not, however, have been against the heraldic customs of the age; for the brave Diego de Ordaz, who boasted of having reached the crater of Popocatepetl when Cortez first penetrated into the Valley of Mexico, received that volcano as an addition to his arms, as did Oviedo the constellation of the Southern Cross, and, earliest of all, Columbus (Examen crit. t. iv. p. 235—240) a fragment of a map of the Antilles.

(379) p. 255. — Humboldt, Ansichten der Natur, Bd. ii. S. 276.

(380) p. 256.— Squier, Nicaragua, its People and Monuments, vol. ii. p. 104. (John Baily, Central America, 1850, p. 75.)

(381) p. 256. — Memorie geologiche sulla Campania, 1849, p. 61. I found the height of the volcano of Jorullo 1680 feet above the plain in which it rose and 4265 feet above the sea.

(382) p. 257. — La Condamine, Journal du Voyage à l'Équateur, p. 163; the same, in the Mesure de trois Degrés de la Méridienne de l'Hémisphère austral, p. 56.

(383) p. 257. — At the country-house of the Marques de Selvalegre, the father of my unfortunate companion and friend Don Carlos Montufar, one was often inclined to attribute the bramidos — which resembled the firing of a distant battery of heavy guns, and were heard with exceedingly unequal intensity, the direction of the wind, and the state of the atmosphere, temperature, &c., remaining unchanged, — not to Sangay, but to Guacamayo, a mountain forty miles nearer, at the foot of which a path leads from Quito by the Hacienda de Antisana to the plains of Archidona and the Rio Napo. (See my special map of the Province of Quiros, No. 23 of my Atlas géogr. et phys. de l'Amérique, 1814—1834.) Don Jorge Juan, who heard the Sangay thunder much nearer than I did, says decidedly that the bramidos, which he terms the ronquidos del volcan (Relacion del Viage á la America Meridional, Pt. I. t. ii. p. 569), belong to Sangay, or Volcan de Macas, whose *voice*, if I may use the expression, is very

distinctly characterised. To the Spanish astronomers this voice appeared particularly hoarse, and they, therefore, called it a snore (un ronquido), rather than a roar (bramido). The mysterious noise of the volcano Pichincha, which I heard several times at night at Quito without its being followed by any earthquake, has something clear and ringing, as if chains were made to rattle, or as if masses of glass fell upon each other. Wisse describes the noise of Sangay, when at the mountain itself, as sometimes like rolling thunder, and sometimes detached and sharp, as if one was in the midst of near platoon firing. From the top of Sangay to Payta and San Buenaventura in Choco, where the bramidos of Sangay are heard, the distances, in a south-west direction, are respectively 252 and 348 geographical miles. (Compare Carte de la Prov. de Choco, and Carte hypsométrique des Cordillères, No. 23 and 3 of my Atlas géogr. et phys.) Thus in these regions of wild grandeur, including Tungurahua and Cotopaxi, whose loud noise was heard by me from the Pacific in February 1803 (Kleinere Schriften, Bd. i. S. 384), the voices of four volcanoes may be heard from places but little distant from each other. The ancients speak of the difference of the noise heard in the Æolian islands from the same fiery orifice at different times. (Strabo, lib. vi. p. 276.) In the great eruption (January 23, 1835) of the volcano of Conseguina, situated on the shore of the Pacific, at the entrance of the Gulf of Fonseca, in Central America, the subterranean propagation of sound was such that the noise was heard distinctly on the high plain of Bogota: a distance like that of Etna from Hamburg. (Acosta, in the Viajes cientificos de M. Boussingault á los Andes, 1849, p. 56.)

(384) p. 258. — Kosmos, Bd. iv. S. 230 (English edition, p. 182).

(385) p. 260. — Compare Strabo, lib. v. p. 248, Casaub., ἔχει κοιλίας τινάς, and lib. vi. p. 276. The geographer of Amasia expresses himself, with much geological sagacity, on two different kinds of origin in islands (vi. p. 258): — "Some islands (naming them) are fragments of the main land; others pertain more to the sea; for these latter islands of the high seas (lying far out at sea) were probably raised up from the deep; whereas those lying off promontories, and separated only by a narrow strait, may more reasonably be supposed to have been torn off from the mainland." (This is from Groskurd's German version.) The small group of the Pithecusæ consisted of Ischia, probably originally called Ænaria, and Procida (Prochyta). Why this group should have been supposed to have had apes in it in ancient times, and should have been named from this supposition by the Greeks and the Italian Tyrrhenians — Etruscans therefore — (Strabo, lib. xiii. p. 626: apes in Tyrrhenian were ἄριμοι), remains very obscure, and may perhaps have been connected with the fable of the former inhabitants having been changed into apes by Jupiter. The word ἄριμοι, for apes, recalls

the Arimæ of Homer, Il. ii. 783, and of Hesiod, Theog. v. 301. The words εἰν ἀρίμοις, of Homer, are, in some codices, contracted into one, and it is thus we find the word in Roman writers (Virg. Æn. ix. 716; Ovid. Metam. xiv. 88). Plinius (Hist. nat. iii. 5) even says positively: "Ænaria, Homero Inarime dicta, Græcis Pithecusa . . . . ." The Homeric land of the Arimes, where Typhon lay, was looked for, in antiquity itself, in Cilicia, Mysia, Lydia, in the volcanic Pithecusæ, in the crater Puteolanus, and in the Phrygian Burnt Land (under which Typhon once lay), and even in the Katakekaumene. That apes should have lived in Ischia, so far from the African coast, within historic times, seems the more improbable, because, as I have elsewhere remarked, it is not even proved that apes lived in ancient times on the rock of Gibraltar; for Edrisi (in the twelfth century), and other Arabian geographers who have described the Straits of Hercules so circumstantially, do not mention them. Also Pliny denies the apes in Ænaria, but deduces the name of the Pithecusæ, in the most improbable manner, from πίθος, dolium (a figlinis doliorum). Böckh says: — "It seems to me that the principal thing in this inquiry is that Inarima is a name of the Pithecusæ, which has arisen out of learned interpretations and fiction, as Corcyra would in this way become Scheria; and that Æneas was first connected with the Pithecusæ (Æneæ insulæ) by the Romans, who found their ancestor everywhere in these regions. Nævius also seems to bear witness to this connection with Æneas in the first book of the Punic War."

([386]) p. 260. — Pind. Pyth. i. 31. Compare Strabo, v. p. 245 and 248, xiii. p. 627. We have already remarked (p. 207, Note 285) that Typhon fled from the Caucasus to Lower Italy: as if the myth indicated that the volcanic eruptions in the latter country were less old than in the Caucasian isthmus. The consideration of popular myths cannot be separated from the geography and the history of volcanoes. They often throw light reciprocally upon each other. What would be regarded as the most powerful of the moving forces on the surface of the Earth (Aristot. Meteorol. ii. 8, 3) the wind, the enclosed pneuma, would be recognised as the general cause of volcanic action (fire-emitting mountains and earthquakes). Aristotle's consideration of nature was founded on the reciprocal action of the external and internal subterranean air, on a theory of exhalation, on differences of heat and cold, of moist and dry. (Aristot. Meteor. ii. 8, 1, 25, 31, and ii. 9, 2.) The greater the mass of the winds enclosed in subterranean and submarine hollow passages, and the more they are hindered from moving rapidly and far according to their natural inherent property, the more violent will be the eruptions. "Vis fera ventorum, cæcis inclusa cavernis." (Ovid. Metam. xv. 299.) Between the "pneuma" and the "fire" there is a peculiar relation. (Τὸ πῦρ ὅταν μετὰ πνεύματος ᾖ, γίνεται φλὸξ καὶ φέρεται

ταχέως, Aristot. Meteor. ii. 8, 3; καὶ γὰρ τὸ πῦρ οἷον πνευματος τις φύσις, Theophrast., De Igne, § 30, p. 715.) Also from the clouds, the pneuma suddenly set free sends forth the kindling and far shining thunderbolt (πρηστήρ). "In the Land of Fire, the Katakekaumene of the Lydians," says Strabo (lib. xiii. p. 628), "there are still shown three hollows, fully forty stadia from each other, which are called the Bellows; there lie over them rough hills, probably piled up by the glowing masses which have been blown out." He had previously said (lib. i. p. 57) that "between the Cyclades (Thera and Therasia) flames of fire had for four days burst forth from the sea, so that the whole sea boiled and burnt; and gradually an island formed of glowing masses was heaved up as by a lever." All these phenomena, so well described, are attributed to the compressed winds, acting as elastic vapours. Ancient physics concerned themselves but little with the several varieties of substances; they were dynamic, and regarded the measure of motive force. The view of the increasing warmth of the Earth with increasing depth as the cause of volcanoes and earthquakes, is first found expressed, in the third century, by a Christian bishop in Africa, under Diocletian. (Kosmos, Bd. iv. S. 244; English edition, p. 197.) The Pyriphlegethon of Plato, as a stream of fire circulating in the interior of the earth, feeds all lava-giving volcanoes, as noticed above in the text, p. 261. In the earliest presentiments of men, and within a small circle of ideas, we find the germs of that which we now think we can explain under the form of other symbols.

([387]) p. 262. — Mount Edgecombe, or Mount St. Lazarus, on the small island (Croze's island) which lies west of the larger island of Sitka or Baranow in Norfolk Sound, and which had already been seen by Cook, is a hill of only 2770 feet high, composed partly of basalt rich in olivine, and partly of felspathic trachyte. Its last great eruption, which brought much pumice to the surface, was in 1796. (Lütké, Voyage autour du Monde, 1836, t. iii. p. 15.) Eight years afterwards, Captain Lisiansky went to the summit, where there is a crater lake. He found at that time no indications of activity at any part of the mountain.

([388]) p. 264. — As early as under the Spanish dominion, in 1781, the Spanish engineer, Don José Galisteo, had found, for the surface of the Laguna of Nicaragua, a height only six feet above that found by Baily in his different levellings in 1838. (Humboldt, Rel. hist. t. iii. p. 321.)

([389]) p. 265. — Compare Sir Edward Belcher, Voyage round the World, vol. i. p. 185. I found myself in the Papagayo storm, according to my chronometric longitude 19° 11′ West of the meridian of Guayaquil, or in 99° 07′ W. of Greenwich, 880 geographical miles west of the shore of Costa Rica.

(390) p. 265. — My earliest writing on the subject of a range of seventeen Guatemala and Nicaragua volcanoes is in the geographical Journal of Berghaus (Hertha, Bd. vi. 1826, S. 131—161). At that time I could avail myself, in addition to the old chronicles of Fuentes (lib. ix. cap. 9), only of the important Compendio de la Historia de la Ciudad de Guatemala, by Domingo Iguarros, and of three maps, by Galisteo (from a survey made by order of Matias de Galvez, Viceroy of Mexico, 1781), by José Rossi y Rubi (Alcalde Mayor de Guatemala, 1800), and by Joaquin Ysasi and Antonio de la Cerda (Alcalde de Granada), which I possess, principally in manuscript. Leopold von Buch, in the French version of his work on the Canary islands (Descr. phys. des Iles Canaries, 1836, p. 500—514), enlarged my sketch in a masterly manner; but the uncertainty which then prevailed respecting geographical names, and which led, in some cases, to one name being confounded with another, gave rise to many doubts; these have now, for the most part, been set at rest by the fine map of Baily and Saunders, by Molina's Bosquejo de la Republica de Costa Rica, and by the great and very meritorious work of Squier (Nicaragua, its People and Monuments, with Tables of the comparative Heights of the Mountains in Central America, 1852; see vol. i. p. 418, and vol. ii. p. 102). The important work promised to us by Dr. Oersted, under the title "Schilderung der Naturverhältnisse von Nicaragua und Costa Rica," in addition to the botanical and zoological investigations which were the principal objects of the author's journeys, will also throw light on the geology of Central America; which he traversed, in a variety of directions, from 1846 to 1848, and from whence he brought back with him to Copenhagen a collection of rock-specimens. I owe to his kind communications some interesting rectifications of my fragmentary work. From a careful comparison of the materials which I now possess, including also some very valuable ones from the Prussian Consul-General in Central America, Herr Hesse, the following table of the volcanoes of Central America has been drawn up, proceeding from South to North: —

On the central high plain of Cartago (4646 feet), in the republic of Costa Rica (N. lat. 10° 9′), rise the three volcanoes of Turrialva, Irasu, and Reventado of which the two first are still active.

Volcan de Turrialva* (about 11,000 feet) is, according to Oersted, only divided from Irasu by a deep narrow cleft. Its summit, from which columns of smoke rise, has not been ascended.

Volcan de Irasu*, also called the volcano of Cartago (11,096 feet), to the north-east of the volcano of Reventado, is the principal seat of volcanic activity in Costa Rica; yet it is remarkably accessible; on the southern side there is a succession of terraces, the summit, from whence both oceans are visible, may

be reached almost entirely on horseback. The cone of cinders and rapilli, about 1000 feet high, rises out of an encircling ridge (a crater of elevation). On the flatter north-eastern portion of the summit lies the proper crater, between 7000 and 8000 feet in circumference, and which never sent forth streams of lava. Its eruptions of scoriæ have often been accompanied, in 1723, 1726, 1821, and 1847, by earthquakes which have destroyed towns, and have extended from Nicaragua or Rivas to Panama. (Oersted.) Dr. Carl Hoffmann, in a recent ascent of Irasu, in May 1855, examined the summit crater and the orifices of eruption more closely. The height of the volcano is, according to a trigonometric measurement by Galindo, 12,000 Spanish (11,000 English) feet. (Bonplandia, 1856, No. 3.)

El Reventado (9486 feet), with a deep crater, whose southern margin has fallen in, and which was formerly filled with water.

Barba (about 8500 feet), north of San José, the capital of Costa Rica, with a crater which encloses several little lakes.

Between the volcanoes of Barba and Orosi there is a line of volcanoes, which, running east and west, crosses the principal chain, of which the direction in Nicaragua and Costa Rica is S.E.—N.W. On this cross-fissure rise, beginning from the east, Miravalles and Tenorio (each about 4700 feet high); in the middle, south-east of Orosi, Rincon, also called Rincon de la Vieja* (Squier, vol. ii. p. 102), which every spring, at the beginning of the rainy season, has small eruptions of ashes; and most to the west, near the little town of Alajuela, the volcano of Votos*, rich in sulphur (7513 feet). Dr. Oersted compares this phænomenon of the direction of volcanic activity over a cross-fissure, with the east and west direction, which I found in the Mexican line of volcanoes from sea to sea.

Orosi*, still active, in the most southern part of the State of Nicaragua (5220 feet); probably the Volcan del Papagayo on the chart in the Deposito Hidrografico.

The two volcanoes of Mandeira and Ometepec* (4160 and 5220 feet), on a small island in the Laguna of Nicaragua, called by the Aztec inhabitants of the district, "ome teptl" or "two mountains." (Compare Buschmann, Aztekische Ortsnamen, S. 178 and 171.) The island-volcano Ometepec, wrongly called by Ignarros, Ometep (Hist. de Guatem. t. 1, p. 51), is still active. It is drawn in Squier, vol. ii. p. 235.

The extinct crater of the island Zapatera, but little raised above the level of of the sea. The period of its former eruptions is wholly unknown.

The volcano of Momobacho, on the western shore of the Laguna de Nicaragua, a little to the south of the town of Granada. As this town (which is also called Mombacho, Oviedo, Nicaragua, ed. Ternaux, p. 245) is situated between this vol-

cano and Massaya; pilots designate sometimes one and sometimes the other of these mountains by the indefinite name of the Volcano of Granada.

Massaya (Masaya) has been described more fully in the text, p. 253—255. It was formerly as active as Stromboli, but has been extinct since the great eruption of lava in 1670. According to the interesting account by Dr. Scherzer (Sitzungsberichte der philos. hist. Classe der Akad. der Wiss. zu Wien, Bd. xx. S. 58), in April 1853, clouds of steam were again emitted from a newly opened crater. The volcano of Massaya is situated between the two lakes of Nicaragua and Managua, to the west of the town of Granada. Massaya is not synonymous with Nindiri; but Massaya and Nindiri * form a "twin volcano," with two summits and two different craters, both of which have given out lava. The stream of lava from Nindiri in 1775 reached the lake of Managua. The equal height of the two volcanoes so near to each other is stated to be only 2450 feet.

Volcan de Momotombo* (7030 feet), active; subterranean thunder often heard, without smoke being seen; in N. lat. 12° 28′, at the north end of the Laguna de Managua, over against the small island of Momotombito, rich in sculptured remains. (See the drawing of Momotombo in Squier, vol. i. p. 233 and 302—312.) The Laguna de Managua is between 27 and 28 feet higher than the Laguna de Nicaragua, which is more than twice as large, and has no island-volcano.

From hence to the Gulf of Fonseca or Conchagua, at a distance of twenty miles from the coast line of the Pacific, there extends a line running S.E.—N.W. of six volcanoes, near to each other, and bearing the common name of Los Maribios. (Squier, vol. i. p. 419, vol. ii. p. 123.)

El Nuevo*, wrongly called Volcan de las Pilas, because the eruption of the 12th of April 1850, took place at the foot of that mountain: a considerable eruption of lava almost in the plain itself! (Squier, vol. ii. p. 105—110.)

Volcan de Telica *, visited in the 16th century (about 1529) by Oviedo, during its activity; situated to the east of Chinendaga, near Leon de Nicaragua, therefore rather out of the direction before assigned. This important volcano, which emits sulphureous vapours from a crater 300 feet deep, was ascended a few years ago by my friend, Professor Julius Pröbel: he found the lava composed of glassy felspar and augite. (Squier, vol. ii. p. 115—117.) On the summit, 3517 feet high, there is a crater in which the vapours deposit great masses of sulphur. At the foot of the volcano there is a mud-spring (Salse ?).

El Viejo*, the northernmost of the crowded range of six volcanoes. It was ascended and measured by Captain Sir Edward Belcher in 1838. The result of his measurement was 5560 feet: a later measurement by Squier gave 6000 feet.

This volcano, which was very active in Dampier's time, is still burning. The eruptions of burning scoriæ are often seen in the town of Leon.

Quanacaure: rather to the north, out of the line from El Nuevo to El Viejo, only twelve miles from the coast of the Gulf of Fonseca.

Consequina*, on the promontory which runs out at the southern end of the Gulf of Fonseca (N. lat. 12° 50′); celebrated for the dreadful eruption, preceded by earthquake, 23rd January 1835. The great darkness produced by the fall of ashes, similar to that which has sometimes been occasioned by Pichincha, lasted forty-three hours. At a few feet distant torches could not be perceived, respiration was impeded, and subterranean noises, resembling the discharge of heavy ordnance, were heard not only in Balize, on the peninsula of Yucatan, but also in Jamaica and on the high plain of Bogota, the latter being more than 8500 feet above the sea, and almost 560 geographical miles distant. (Juan Galindo in Silliman's American Journal, vol. xxviii. 1835, p. 332—336; Acosta, Viajes á los Andes, 1849, p. 56; and Squier, vol. ii. p. 110—113; drawings, p. 163 and 165.) Darwin (Journal of Researches during the Voyage of the Beagle, chap. 14, p. 291) calls attention to a remarkable coincidence of phænomena: after a long slumber the volcanoes of Conseguina in Central America, of Aconcagua and Corcovado (S. lat. $32\frac{3}{4}$° and $43\frac{1}{2}$°) in Chili, broke out on the same day. Was this an accident?

Volcano of Conchagua, or of Amalapa, at the northern entrance of the Gulf of Fonseca, opposite to the volcano of Conseguina, at the fine Puerto de la Union, the port of the neighbouring town of San Miguel.

From the State of Costa Rica to the volcano of Conchagua, the range of twenty volcanoes follows a S.E.—N.W. direction, but at Conchagua, where it enters the State of San Salvador, which, in a length of 160 geographical miles, has five volcanoes, all still more or less active, the line of volcanoes, like the coast line towards the Pacific, turns more E.S.E.—W.N.W. or even almost E.—W.; while on the eastern (Atlantic) side, about Cape Gracias á Dios, the coast-line swells out suddenly in the territories of Honduras and Los Mosquitos. (Compare text, p. 263.) It is not, as there remarked, until the lofty volcanoes of Old Guatemala are passed, about the Laguna of Atitlan, that the former general direction, N. 45° W., returns, and continues to Chiapa and the isthmus of Tehuantepec, when the abnormal E.—W. direction reappears in non-volcanic chains. The remaining four volcanoes in the State of San Salvador, besides Conchagua, are:

The volcano of San Miguel Bosotlan* (N. lat. 13° 35′), near the town of that name: the finest and most regular trachytic cone, next to the island-volcano Ometepec, in the lake of Nicaragua. (Squier, vol. ii. p. 196.) The volcanic

forces are very active in Bosotlan : it had a great outpouring of lava on the 20th of July 1844.

Volcano of San Vicente*, west of Rio de Lempa, between the towns of Sacatecoluca and Sacatelepe. A great eruption of ashes took place, according to Juarros, in 1643; and in January 1835, a very destructive earthquake accompanied an eruption of long duration.

Volcano of San Salvador (N. lat. 13° 47′), near the town of the same name. The latest eruption took place in 1656. The whole district around is exposed to severe earthquake-shocks; that of the 16th of April 1854, which was not preceded by any noise, overthrew almost all the buildings in San Salvador.

Volcano of Izalco*, near the village of the same name ; often produces muriate of ammonia. The first historically known eruption took place on the 23rd of February 1770 ; subsequent eruptions, of which the light was seen at great distances, took place in April 1798, 1805 to 1807, and 1825. (See above p. 255—256, and Thompson, Official Visit to Guatemala, 1829, p. 512.)

Volcan de Pacaya* (N. lat. 14° 23′), about twelve miles south-east of the town of New Guatemala, on the little Alpine lake Amatitlan ; a very active, often flaming, volcano ; an extended ridge with three rounded summits. It had great eruptions in 1565, 1651, 1671, 1677, and 1775 ; the last of these, in which much lava flowed, was described by Juarros, who himself witnessed it.

Next follow the two volcanoes of Old Guatemala, named De Agua and De Fuego ; in 14° 12′ N. lat., near the coast.

Volcan de Agua : a trachytic cone near Escuintla, higher than the Peak of Teneriffe ; surrounded by masses of obsidian (evidences of ancient eruptions ?). This volcano, which enters the region of perpetual snow, received its name from a great inundation which was attributed to it, and which, in September 1541, destroyed the first city of Guatemala, and occasioned the foundation of the second, now called Antigua Guatemala, which was built more to the N.N.W. (Was the inundation produced by earthquake and melting of snow ?)

Volcan de Fuego*, near Acatenango, twenty miles W.N.W. from the Volcan de Agua. For their relative situation see the rare map (engraved at Guatemala and given to me from thence) of the Alcalde mayor, Don José Rossi y Rubi, entitled, Bosquejo del Espacio que media entre los estremos de la Provincia de Suchitepeques y la Capital de Guatemala, 1800. The Volcan de Fuego is still active, though much less so than formerly. The earlier great eruptions took place in 1581, 1586, 1623, 1705, 1710, 1717, 1732, 1737, and 1799 ; but it was not so much these as the destructive earthquakes which accompanied them, that induced the Spanish Government, in the second half of the last century, to forsake the second site, where the ruins of La Antigua Guatemala now stand,

and to oblige the inhabitants to establish themselves more to the north, in the new town of Santiago de Guatemala. On this, as on the removal of the site of Riobamba and other towns near the volcanoes of the Andes, there was much dogmatic and passionate debate respecting the choice of a locality, which might be supposed from previous experience to be little exposed to the effects of neighbouring volcanoes, streams of lava, eruptions of scoriæ, and earthquakes! The Volcan de Fuego had a great eruption in 1852, when it sent forth a stream of lava towards the shore of the Pacific. Captain Basil Hall measured, under sail, the two volcanoes of Old Guatemala, and found for the Volcan de Fuego 14,665, and for the Volcan de Agua 14,903 feet. Poggendorff examined the data on which these results were based, and inferred a less height, *i. e.* about 13,110 feet for the mean of the two.

Volcan de Quesaltenango* (N. lat. 15° 10′), burning since 1821, and giving out smoke: near the town of the same name: the three conical mounts which bound the Alpine lake, Atitlan, on the south, are also supposed to be burning. The volcano of Tajamulco named by Juarros cannot well be identical with the volcano of Quesaltenango, as the latter is forty geographical miles to the N.W. of the village of Tajamulco, south of Tejutla.

What are the two volcanoes of Sacatepeques and Sapotitlan named by Funel; or Brué's Volcan de Amilpas ?

The great Volcano of Soconusco: near the boundary of Chiapa, twenty-eight miles south of Ciudad Real, in N. lat. 16° 2′.

At the conclusion of this long note I must again recall that the barometric determinations of height are partly given by Espinache, and partly taken from the writings and maps of Baily, Squier, and Molina, and that they are expressed in Paris feet (which in the translation have been converted into English feet).

(391) p. 265.— Of the volcanoes cited by me as active either formerly or at present, the following eighteen, almost half the number, may be regarded as still more or less so: Irasu and Turrialva, near Cartago; el Rincon de la Vieja; Votos (?) and Orosi; the island-volcano Ometepec, Nindiri, Momotombo, el Nuevo (at the foot of the trachytic mountain las Pilas), Telica, el Viejo, Conseguina, San Miguel Bosotlan, San Vicente, Izalco, Pacaya, Volcan de Fuego (de Guatemala), and Quesaltenango. The most recent eruptions were those of el Nuevo, 18th April 1850; San Miguel Bosotlan, 1848; Conseguina and San Vicente, 1835; Izalco, 1825; Volcan de Fuego, 1799 and 1852; and Pacaya 1775.

(392) p. 266.— Compare Squier, Nicaragua, vol. ii. p. 103, with p. 106 and 111, as well as his earlier short Notice on the Volcanoes of Central America, 1850, p. 7; and L. de Buch, Iles Canaries, p. 506; where mention is made of the

stream of lava which issued from Nindiri in 1775, and which has recently been seen again by a very scientific traveller, Dr. Oersted.

([393]) p. 268.—See all the bases on which these determinations of position in Mexico are founded, and their comparison with the observations of Don Joaquin Ferrer, in my Recueil d'Observ. Astron. vol. ii. p. 521, 529, and 536—550, and Essai Pol. sur la Nouv. Espagne, t. i. p. 55—59 and 176, t. ii. p. 173. Respecting the position of the Volcano of Colima I had myself early expressed doubt (Essai Pol. t. i. p. 68, and t. ii. p. 180). By altitudes taken by Captain Basil Hall under sail, that volcano would be in N. lat. 19° 36′, or half a degree north of the position which I had inferred from the Itineraries; but without absolute determinations for Selagua and Petatlan, which I used as points of departure. The latitude and the elevation (12,003 English feet), given in the text, are taken from Admiral Beechey (Voyage, Pt. II. p. 587). The most recent map by Laurie (the Mexican and Central States of America) gives 19° 20′ for the latitude. The latitude of Jorullo may also be two or three minutes wrong, as when there I was much engaged with geological and topographical examinations, and neither sun nor stars were visible for the determination of latitude. Compare Basil Hall, Journal written on the coast of Chili, Peru, and Mexico, 1824, vol. ii. p. 579; Beechey, Voyage, Pt. II. p. 587; and Humboldt, Essai Pol. t. i. p. 68, t. ii. p. 180. In the faithful and highly picturesque views which Moritz Rugendas has taken of the Volcano of Colima, and which are preserved in the Berlin Museum, one may distinguish two mountains near each other, one the proper volcano from which smoke always issues, which has but little snow, and the other, the loftier Nevada, which enters deep into the region of perpetual snow.

([394]) p. 272.—The following is the result of the determinations of latitude and longitude of the five linear groups of volcanoes in the Andes, and also a statement of the distances between the groups, elucidating the relative amount of the volcanic and non volcanic spaces :—

I. Group of Mexican volcanoes. The fissure on which they rise runs east and west from Orizaba to Colima, for a distance of 392 geographical miles, between 19° and 19° 20′ N. lat. The Volcano of Turtla stands apart, 128 miles to the east of Orizaba, near the coast of the Gulf of Mexico, in a parallel (18° 28′) half a degree more to the south.

II. Distance of the Mexican from the next, the Central American group (being the distance from the Volcano of Orizaba to that of Soconusco in the E.S.E.—W.N.W. direction) : 300 miles.

III. Group of Central American volcanoes: its length from S.E. to N.W., from Soconusco to Turrialva in Costa Rica, above 680 miles.

IV. Distance of the Central-American group from that of New Granada and Quito: 628 miles.

V. Group of New Granada and Quito; its length from the eruption in the Paramo de Ruiz, north of the Volcan de Tolima, to the Volcano of Sangay: 472 miles. The part of the chain of the Andes between the Volcano of Puracé near Popayan and the southern part of the volcanic mountain-knot of Pasto runs N.N.E.—S.S.W. Far to the east of the volcanoes of Popayan, at the sources of the Rio Fragua, there is a very isolated volcano which I have entered in my general map of the mountain-knots of the South-American Cordilleras from the accounts communicated to me by the missionaries of Timana; distance from the sea-shore, above 152 miles.

VI. Distance of the New Granada and Quito group from that of Peru and Bolivia: 960 miles; which is the greatest distance without volcanoes.

VII. Group of Peru and Bolivia, from the Volcan de Chacani and Arequipa to the Volcano of Atacama ($16\frac{1}{4}^\circ$ — $21\frac{1}{2}^\circ$ S. lat.): 420 miles.

VIII. Distance of the group of Peru and Bolivia from the Chilian volcanic group: 540 miles. From the part of the desert of Atacama, at the edge of which rises the Volcano of San Pedro, to far beyond Copiapo, and even to the Volcano of Coquimbo (30° 5′ S. lat.) in the long Cordillera west of the two provinces of Catamarca and Rioja, there is not a single volcanic cone.

IX. Chilian group: from the Volcano of Coquimbo to that of San Clemente, 968 miles.

These estimations of the length of the Cordilleras, with the curvatures arising from changes of direction in the axis, from the parallel of the Mexican volcanoes (in $19\frac{1}{4}^\circ$ N. lat.), to the Volcano of San Clemente in Chili (46° 8′ S. lat.), give for an entire distance of 4968 miles a space of 2,540 miles occupied by five linear groups of volcanoes (Mexico, Central America, New Granada and Quito, Peru and Bolivia, and Chili), and a space of 2428 miles probably without volcanoes. The spaces are therefore nearly equal. I have given very definite numerical relations, such as could be derived from a careful discussion of my own and other maps and materials, in the hope of inducing others to further rectification and improvement.

([395]) p. 272.— The group of Mexican volcanoes comprises those of Orizaba *, Popocatepetl *, Toluca (or Cerro de San Miguel de Tutucuitlapilco), Jorullo*, Colima *, and Turtla*. The still burning volcanoes are here, as in other similar lists, marked by an asterisk.

([396]) p. 272.—The volcanoes of the Central-American group are enumerated in Notes 390 and 391.

([397]) p. 272. — The group of New Granada and Quito comprises the Paramo

y Volcan de Ruiz *, the volcanoes of Tolima, Puracé *, and Sotará near Popayan; the Volcan del Rio Fragua (a river which falls into the Caqueta); the Volcanoes of Pasto, el Azufral *, Cumbal *, Tuquerres *, Chiles, Imbaburu, Cotocachi, Rucu-Pichincha, Antisana (?), Cotopaxi * Tungurahua *, Capac-Urcu or Altar de los Collanes (?), and Sangay *

([398]) p. 272.—The group of Southern Peru and Bolivia comprises the following fourteen volcanoes, proceeding from North to South :—

Volcano of Chacani (according to Curzon and Meyen also called Charcani), visible from the town of Arequipa, on the right bank of the Rio Quilca; according to Pentland, the most accurate geological explorer of this region, in S. lat. 16° 11; 32 miles south of the Nevado of Chuquibamba, estimated to exceed 19,000 feet in height. Manuscript Notices in my possession give to the Volcano of Chacani 19,600 feet. On the south-eastern part of the summit Curzon saw a large crater.

Volcano of Arequipa* : S. lat. 16° 20′; twelve miles north-east of the town of the same name. Respecting its height (18,877 feet) see above, p. 248, and Note 369. Thaddæus Hänke, the botanist of Malaspina's expedition (1796), Samuel Curzon of the United States of North America (1811), and Dr. Weddell (1847) ascended the summit. Meyen, in August 1831, saw great columns of smoke rise from it; a year before it had erupted scoriæ, but never lava. (Meyen's Reise um die Erde, Th. II. S. 33.)

Volcan de Omato: S. lat. 16° 50′; it had a violent eruption in 1667.

Volcan de Uvillas, or Uvinas: south of Apo; its latest eruptions were in the 16th century.

Volcan de Pichu-Pichu: sixteen miles east of the town of Arequipa (lat. 16° 25′ S.), not far from the pass of Cangallo, 9,673 feet above the sea.

Volcan Viejo: 16° 55′ S.; an enormous crater with lava streams and much pumice.

The six last-named volcanoes compose the group of Arequipa.

Volcan de Tacora, or Chipicani, according to Pentland's fine Map of the Lake of Titicaca: 17° 45′ S. height 19,735 feet.

Volcan de Sahama*: 22,350 feet high; 18° 7′ S.; a truncated cone of the most regular form; see above, Note 371. Sahama, according to Pentland, is 870 French feet higher than Chimborazo, but 6240 French feet lower than Mount Everest in the Himalaya, which is now regarded as the highest known summit on the globe. According to the last official accounts from Colonel Waugh, 1st March 1856, the four highest moun-

tains in the Himalaya are : Mount Everest, or Gaurischanka, north-east of Katmandoo, 29,000 feet; Kinchinjinga, north of Darjeeling, 28,154 feet; Dhawalagiri, 26,825 feet ; and Tschumalari (or Chamalari), 23,930 feet.

Volcano Pomarape, 21,700 feet, 18° 8′ S., almost a twin mountain to the next volcano.

Volcano Parinacota, 22,033 feet, 18° 12′ S.

The group of four trachytic cones : Sahama, Pomarape, Parinacota, and Gualatieri, which lies between the parallels of 18° 7′ and 18° 25, is, according to Pentland, higher than Chimborazo, higher than 21,424 feet.

Volcano Gualatieri * : 21,960 feet, 18° 25′ S.; in the Bolivian province Carangas ; according to Pentland burning strongly. (Hertha, Bd. xiii. 1829, S. 21.)

Not far from the Sahama group, in 18° 7′ to 18° 25′ S., the direction both of the series of volcanoes and of the whole chain of the Andes to the west of it, suddenly alters from N.W.—S.E. to N.—S., which continues to be the general direction to the Straits of Magellan. I have already spoken (Kosmos, Bd. i. S. 310 and 472 ; English edition, p. 284 and Note 347) of this important inflection which is analogous to the one in the Bight of Biafra on the west coast of Africa.

Volcano Isluga : 19° 20′ S., in the province of Tarapaca, west of Carangas.

Volcan de San Pedro de Atacama : on the north-eastern edge of the desert of the same name, according to the recent special map of the waterless sandy waste (desierto) of Atacama by Dr. Philippi ; lat. 22° 16′ S., sixteen geographical miles north-east of the little town of San Pedro, not far from the great Nevado de Chorolque.

There is no volcano from 21½° to 30° S. ; and after this long interruption of 568 miles, volcanic activity first reappears in the Volcano of Coquimbo. For the existence of a Volcano of Copiapo in lat. 27° 28′ is denied by Meyen, though believed by Philippi who knew the country well.

(399) p. 272.— Our geographical and geological knowledge of the Chilian group, or line of volcanoes, is largely indebted to the able investigations of Captain Fitz-Roy and of Charles Darwin, in the memorable Expedition of the "Adventure" and "Beagle." Darwin embraced, with the comprehensive glance and spirit of generalisation which belong to him, the connection in one point of view of earthquake phænomena and volcanic eruptions. The great natural event which, on the 22nd of November 1822, destroyed the town of Copiapo, was accompanied by the elevation of a considerable strip of land along the coast ; and during the very similar phænomenon which, on the 20th of February 1835, so

greatly injured the town of Concepcion, a submarine volcano broke forth near Bacalao Head, on the Island of Chiloe, with a fiery eruption which raged violently for a day and a half. All this, with previous similar occurrences, under similar conditions, confirms the belief, that the range of rocky islets which, south of Valdivia and Fuerte Maullin, lie opposite to the fiords of the mainland; viz. Chiloe, the Archipelago of the Chonos and Huaytecas, the Peninsula de Tres Montes, and the Islas de la Campana, de la Madre de Dios, de Santa Lucia, and los Lobos, from 39° 53′ S. lat. to the entrance of Magellan Strait in 52° 16′, are the jagged crest of a sunken westernmost Cordillera. It is true that we see no open trachytic cone, no volcano, in these fractis ex æquore terris, but single submarine eruptions sometimes following, sometimes preceding, great earthquakes, appear to point to the existence of this western fissure. (Darwin, on the Connexion of Volcanic Phænomena, the Formation of Mountain Chains, and the Effect of the same Powers, by which Continents are elevated: in the Transactions of the Geological Society, second series, vol. v. Pt. III. 1840, p. 606—615 and 629—631; Humboldt, Essai Pol. sur la Nouv. Espagne, t. i. p. 190, and t. iv. p. 287.)

The twenty-four volcanoes of the Chilian group, proceeding from north to south, from the parallel of Coquimbo to 46° S. lat., are as follows:—

a. Between the parallels of Coquimbo and Valparaiso:

Volcan de Coquimbo (30° 5′ S.); Meyen, Th. 1, S. 385.

„ Limari.

„ Chuapri.

„ Aconcagua*: W.N.W. of Mendoza, 32° 39′ S.; height 23,004 feet, according to Kellet (see above, Note 371); but, according to the most recent trigonometric measurement of the engineer Amado Pissis (1854), only 22,301 feet, lower therefore than Sahama, to which Pentland now assigns 22,350 feet; Gilliss, U. S. Naval Astr. Exp. to Chili, vol. i. p. 13: Pissis has given in full the geodetical elements of his measurement (which required eight triangles) in the Anales de la Universidad de Chile, 1852, p, 219.

Peak Tupungato has assigned to it by Gilliss 22,450 feet, and 33° 22′ S.; but in the Map of the Province of Santiago, by Pissis (Gilliss, p. 45), 22,016 feet are given. The latter value (6710 mètres) is retained by Pissis in the Anales de Chile, 1850, p. 12.

b. Between the parallels of Valparaiso and Concepcion:

Maypu*: according to Gilliss (vol. i. p. 13) in 34° 17′ S. lat. (but in his General Map of Chili, no doubt erroneously, in 33° 47′), and the height 17,662 feet; ascended by Meyen. The trachytic rock of the summit has

broken through Upper Jurassic strata in which von Buch recognised Exogyra Couloni, Trigonia costata, and Ammonites biplex, taken from heights of 9600 feet. (Description Physique des Iles Canaries, 1836, p. 471.) No streams of lava, but flames and eruptions of scoriæ from the crater.

Peteroa * : east of Talca, 34° 53′ S.; often burning; and, according to Molina's description, having had a great eruption Dec. 3, 1762; was visited, in 1831, by the able explorer of nature, Gay.

Volcan de Chillan : 36° 2′ S.; the district has been described by the Missionary Havestadt of Munster. Near it is the Nevado Descabezado (35° 1′ S.), which Domeyko ascended, and Molina (erroneously) stated to be the highest mountain in Chili. Gilliss estimates its height at 13,100 feet. (U. S. Naval Astr. Exp. 1855, vol. i. p. 16 and 371.)

Tucapel : west of the town of Concepcion; also called Silla Veluda; perhaps an unopened trachytic mount connected with the burning volcano of Antuco.

c. Between the parallels of Concepcion and Valdivia :

Antuco * : 37° 7′ S.; geologically described in detail by Pöppig, "a basaltic crater of elevation, out of which the trachytic cone rises; lava streams burst forth at the foot of the cone, and more rarely from the summit crater." (Pöppig, Reise in Chile und Peru, Bd. i. S. 364.) One of these streams was still flowing in 1828. In 1845, the diligent explorer Domeyko found it in full activity; he gave its height only 8918 feet. (Pentland, in Mary Somerville's Phys. Geography, vol. i. p. 186.) Gilliss gives for its height 9242 feet, and mentions new eruptions in 1853. According to an account communicated to me by the last-named distinguished American astronomer it would appear that, in the interior of the Cordillera, on the 25th of Nov. 1847, a new volcano was upheaved forming a Hill * 320 feet high. The sulphurous and fiery eruptions were seen by Domeyko for more than a year. Far to the east of the Volcano Antuco, in a parallel chain of the Andes, Pöppig mentions two other active volcanoes: Punhamuidda * and Unalavquen.*

Volcano Callaqui.

Volcan de Villarica * : 39° 14′ S.

Volcano Chiñal : 39° 35′ S.

Volcan de Panguipulli * : according to Major Philippi in 40¾° S.

d. Between the parallels of Valdivia and the southernmost cape of the Island of Chiloe :

Volcano Ranco.

,, Osorno, or Llanquihue : 41° 9′ S. : height, 7442 feet.

Volcan de Calbuco* : 41° 12′ S.

Volcano Guanahuca (Guanegue ?).

Volcano Minchinmadom : 42° 48′ S. ; height, about 8000.

Volcan del Corcovado* : 43° 12′ S., height, 7509 feet.

Volcano Yanteles (Yntales) : 43° 29′ S. ; height, 8029 feet. On the four last-mentioned heights, see Fitz-Roy (Exped. of the "Beagle," vol. iii. p. 275), and Gilliss, vol. i. p. 13.

Volcano San Clemente: opposite to the Peninsula de Tres Montes, which, according to Darwin, consists of granite; 46° 8′ S. On the great Map of South America by La Cruz, a more southern volcano, called de los Gigantes, is marked opposite to the islands de la Madre de Dios, in 51° 4′ S. Its existence is very doubtful.

The latitudes in the above Table are for the most part taken from the Maps of Pissis, Allan Campbell, and Claude Gay, in the excellent work of Gilliss (1855).

([400]) p. 274.—Humboldt, Kleinere Schriften, Bd. i. S. 90.

([401]) p. 274.—24 January 1804. See my Essai Pol. sur la Nouv. Espagne, t. i. p. 166.

([402]) p. 277.—The mica-schist of the mountain-knot de los Robles, lat. 2° 2′, and of the Paramo de las Papas (lat. 2° 20′), contains two mountain-lakes, Laguna de S. Jago and Laguna del Buey, less than six miles from each other, from the first-named of which flows the Cauca, and from the second the Magdalena River. These rivers are soon after divided from each other by a central mountain-chain, and reunite, in lat. 9° 27′, in the plains of Mombox and Tenerife. The above-mentioned knot, between Popayan, Almaguer, and Timana, is of great importance in regard to the geological question whether the Andes of Chili, Peru, Bolivia, Quito, and New Granada are connected with the chain of the Panama Isthmus, and thus with that of Veragua and the volcanic ranges of Costa Rica and the whole of Central America. In my maps of 1816, 1827, and 1831 (the "mountain-systems" of which have been more widely circulated by Brué in Joaquin Acosta's fine Map of New Granada (1847), and other maps), I have shown the manner in which, in N. lat. 2° 10′, the chain of the Andes trifurcates, the western cordillera running between the valley of the Rio Cauca and the Rio Atrato, the central one between the Cauca and the Magdalena, and the eastern between the Magdalena and the plains, or llanos, which are watered by the tributaries of the Amazons and the Orinoco. I was able to show the special direction of each of these cordilleras from a great number of points which are part of my series of astronomical determinations of places, of which in South America alone I obtained 152 by star culminations.

The Western Cordillera runs east of Rio Dagua, west of Cazeres Roldanilla, Toro and Anserma near Cartago, S.S.W.—N.N.E. to the Salto de San Antonio in the Rio Cauca (lat. 5° 14′), which is south-west of the Vega de Supia. From thence and up to the Alto del Viento, 9600 feet high (Cordillera de Abibe, or Avidi, lat. 7° 12′), the chain increases considerably in height and extent, and in the Province of Antioquia unites with the middle or central cordillera. Farther to the north, towards the sources of the Rios Lucio and Guacuba, the chain sinks and subdivides into ranges of hills. The Cordillera Occidental, which, at the mouth of the Dagua in the Bahia de San Buenaventura, is only about thirty miles from the coast line (lat. 3° 50′), is twice as far from it in the parallel of Quibdo in the Choco (lat. 5° 48′). This remark has some importance, because we must not confound with the western chain of the Andes the high hilly land and the chain of hills which in this province, rich in gold-washings, runs from Novita and Tado along the right bank of the Rio San Juan, and the left bank of the Rio Atrato, from south to north. It is this inconsiderable range of hills which, in the Quebrada de la Raspadura, is traversed by the Canal of the Monk, which connects two rivers (the Rio San Juan, or Noanama, and the Rio Quibdo, an affluent of the Atrato), and thereby brings the two oceans into connection (Humboldt, Essai Pol. t. i. p. 235); and it is also this range which was seen in Captain Kellet's instructive expedition, between the Bahia de Cupica, in lat. 6° 42′, so long fruitlessly extolled by me, and the sources of the Napipi, which falls into the Atrato. (Compare Essai Pol. t. i. p. 231; and Robert Fitz-Roy's Considerations on the great Isthmus of Central America, in the Journal of the Royal Geogr. Soc. vol. xx. 1851, p. 178, 180, and 186.)

The middle chain of the Andes (Cordillera Central), persistently the highest, entering the region of perpetual snow, and running throughout its whole extent, like the western chain, almost north and south, begins about thirty-four miles north-east of Popayan with the Paramos of Quanacos, Huila, Iraca, and Chinche. Further on towards the north rise, between Buga and Chaparral, the long extended ridges of the Nevado de Baraguan (lat. 4° 11′), la Montaña de Quindio, the snow-covered truncated cone of Tolima, the Volcano and Paramo de Ruiz, and the Mesa de Herveo. These high and rude mountain solitudes, designated in the Spanish language by the name of Paramos, are distinguished by temperature and by a peculiar character of vegetation, and in the part of the tropics which I am now describing, occupy elevations which, by many measurements, may be stated to average from 9500 to 11,000 French feet (10,124 to 11,723 Engl.). In the parallel of Mariquita, the Herveo, and the Salto de San Antonio, begins the massive junction, or coalition, of the western and central chain which has been already alluded to. This coalition is most striking between the Salto de San

Antonio and the Angostura and Cascada de Caramanta near Supia. There lies the highland and the difficultly accessible Province of Antioquia which, according to Manuel Restrepo, extends from $5\frac{1}{4}°$ to $8\frac{3}{4}°$ N. lat., and in which, still proceeding from south to north, we name successively : Arma, Sonson; north of the sources of the Rio Samana ; Marinilla, Rio Negro (6842 feet), and Medellin (4847 feet) ; the plateau of Santa Rosa (8466 feet); and the Valle de Osos. Beyond Cazeres and Zaragoza, towards the confluence of the Cauca and the Nechi, the mountain-chain properly so called disappears; and the eastern declivity of the Cerros de San Lucar which, when navigating and surveying the Magdalena River, I saw from Badillas, in 8° 1′ N., and Paturia, 7° 36′ N., is only rendered sensible by the contrast with the broad plain of the river.

The Eastern Cordillera offers the geographical interest not only of dividing the whole northern mountain-system of New Granada from the lowlands, from which the waters flow partly through the Caguan and Caqueta to the Amazons, and partly through the Guaviare, Meta, and Apure to the Orinoco ; but also of being decidedly connected with the coast-chain of Caracas. There is here a conjunction of mountain-ridges which have been elevated over two fissures of very different directions, and probably also at very different times. The eastern cordillera departs much more than the other two from the direction of the meridian, deviating so much towards N.E. that at the snow-covered mountains of Merida, in 8° 10′ N. lat., it is already 5° more easterly than at the mountain-knot de los Robles not far from the Ceja and Timana. North of the Paramo de la Suma Paz, east of la Purificacion, on the western declivity of the Paramo of Chinzaga, at a height of only 8760 feet, there rises above the oak forest the fine but treeless high plain of Bogotà (lat. 4° 36′). It extends over about eighteen (German) geographical square miles, and its situation presents a striking similarity to that of the basin of Kashmeer (which is however, according to Victor Jacquemont, 3410 feet lower, and belongs to the south-western declivity of the Himalayan chain). Next to the plateau of Bogotà and the Paramo de Chinzaga there follow in the eastern cordillera of the Andes, towards the north-east, the Paramos of Guachaneque, above Tunja; of Zoraca, above Sogamoso; of Chita (16,000 feet ?) near the sources of the Rio Casanare, a tributary of the Meta; of the Almorzadero (12,854 feet) near Socorro ; of Cacota (10,986 feet) near Pamplona ; and of Laura and Porquera near la Grita. Here, between Pamplona, Salazar, and Rosario (between 7° 8′ and 7° 50′ N. lat.), is the small mountain-knot, from whence a crest stretches northward towards Ocaña and Valle de Upar, west of the Laguna de Macaraibo, and unites with the advanced posts of the Sierra Nevada de Santa Marta (19,000 feet ?). The higher and more considerable crest continues to run in the previous N.E. direction towards Merida, Truxillo,

and Barquisimeto, there to unite itself with the granitic coast-chain of Venezuela, east of the Laguna de Macaraibo and west of Puerto Cabello. From the Grita and the Paramo de Porquera, the Eastern Cordillera rises again to an extraordinary height. There follow, between the parallels of 8° 5′ and 9° 7′, the Sierra Nevada de Merida (Mucuchies), explored by Boussingault, and of which Codazzi has assigned the height, by trigonometrical measurement, 15,165 feet, and the four Paramos of Timotes, Niquitao, Bocono, and de las Rosas, full of the most beautiful alpine plants. (Compare Codazzi, Resumen de la Geografia de Venezuela, 1841, p. 12 and 495 ; also my Asie Centrale, on the height of perpetual snow in this zone, t. iii. p. 258—262.) The western cordillera is entirely without volcanic activity ; in the middle one it prevails up to Tolima and the Paramo de Ruiz, which, however, are almost three degrees of latitude from the Volcan de Puracé. The eastern cordillera has near its eastern declivity, at the origin of the Rio Fragua, north-east of Mocoa and south-east of Timana, a smoking hill : more distant from the shore of the Pacific than any other still active volcano in the New Continent. An exact knowledge of the local relations of the volcanoes to the ramifications of the mountain-chains is highly important towards the completion of the geology of volcanoes. All older maps, excepting that of the highland of Quito, are only calculated to mislead.

(403) p. 277.—Pentland, in Mary Somerville's Phys. Geography, 1851, vol. i. p. 185. The Peak of Vilcanoto (17,020 feet, in 14° 28′ lat.), a part of the mass of mountains of that name, and directed east and west, forms the northern extremity of the high plain in which the Lake of Titicaca, 88 miles long, appears only a small inland sea

(404) p. 278.—Compare Darwin, Journal of Researches into the Natural History and Geology during the Voyage of the "Beagle," 1845, p. 275, 291, and 310.

(405) p. 280.— Junghuhn, Java, Bd. i. S. 79.

(406) p. 280.—Junghuhn, Java, Bd. iii. S. 155 ; and Göppert, die Tertiärflora auf der Insel Java nach den Entdeckungen von Junghuhn (1854), S. 17. The absence of monocotyledons is, however, only to be understood of the silicified trunks of trees found on the surface and particularly in the rivers of the Bantam district ; in the subterrannean coal-beds remains of palms are found, belonging to the two genera of Flabellaria and Amesoneuron. See Göppert, S. 31 and 35.

(407) p. 281.—On the signification of the word Mèru, and the conjectures communicated to me by Burnouf respecting its connection with Mêra (a Sanscrit word for sea), see my Asie Centrale, t. i. p. 114—116; and Lassen's In-

dische Alterthumskunde, Bd. i. S. 847 ; he is inclined to regard the name as not of Sanscrit origin.

(408) p. 281.—Kosmos, Bd. iv. S. 284, and Anm. 6 (English edition, p. 239, and Note 330).

(409) p. 281.—Gunung is the Javanese word for mountain; in Malay, gûnong. It is remarkable that its use does not extend further over the enormous range occupied by languages of the Malay stock. See the comparative table of words in my brother's work, Ueber die Kawi Sprache, Bd. ii. S. 249, No. 62. As it is the custom to prefix this word to the names of mountains in Java, it is indicated in the text for the most part by a simple G.

(410) p. 281.—Léop. de Buch, Description Physique des Iles Canaries, 1836, p. 419. But it is not only Java (Junghuhn, Th. i. S. 61, and Th. ii. S. 547) which has a mountain, G. Semeru, a little higher than the Peak of Teneriffe, being 12,235 feet ; the also still active Indrapura in Sumatra, which would seem to have been less exactly measured, is supposed 11,500 French feet (12,256 Engl.) ;—(See Th. i. S. 78, and profile map, No. 1.) Next to Indrapura come, in Sumatra, Telaman one of the summits of Ophir (not 13,834, but only 9603 feet high), and Merapi (according to Dr. Horner, 9570 feet) the most active of the thirteen volcanoes in Sumatra, which, however (Th. ii. S. 294, and Junghuhn's Battaländer, 1847, Th. i. S. 25), must not be confounded with two Javanese volcanoes of similar name : the celebrated Merapi near Jogjakerta (9208 feet), and the Merapi which is the eastern part of the summit of the Volcano Idjen (8595). The name Meru, combined with the Malayan and Japanese word api, fire, has been supposed to be recognised in Merapi.

(411) p. 282.—Junghuhn, Java, Bd. i. S. 80.

(412) p. 282.—Compare Joseph Hooker, Sketch Map of Sikhim, 1850, and in his Himalaya Journals, vol. i. 1854, Map of part of Bengal ; as well as Strachey, Map of West-Nari, in his Physical Geography of Western Thibet, 1853.

(413) p. 283.—Junghuhn, Java, Bd. ii. fig. IX. S. 572, 596, and 601—604. From 1829 to 1848, the small eruption-crater, Bromo, had eight fiery eruptions. The crater-lake which had disappeared in 1842 had reformed in 1848 ; but according to the observations of B. Van Herwerden, the presence of water had not prevented the ejection of glowing scoriæ, which were hurled to a distance.

(414) p. 283.—Junghuhn, Bd. ii. S. 624—641.

(415) p. 284.— Gunung Pepandajan was ascended by Reinwardt in 1819, and by Junghuhn in 1837. Junghuhn, who examined carefully the parts round the mountain, which are covered with numerous angular blocks of lava, and compared them with all the earliest accounts he could obtain, looks upon the state-

ment which has been circulated in many valuable writings, that during the eruption of 1772 a part of the mountain had fallen in, and an adjacent area cf many square miles had sunk down, as greatly exaggerated. (Junghuhn, B. ii. S. 98 and 100.)

([416]) p. 284.—Kosmos, Bd. iv. S. 495, Anm. 30 (Engl. edition, Note 254), and Voyage aux Régions équinox. t. ii. p. 16.

([417]) p. 285.—Junghuhn, Bd. ii. S. 241—246.

([418]) p. 286.—Junghuhn, Bd. ii. S. 566, 590, and 607—609.

([419]) p. 286.—Leop. von Buch, Phys. Beschr. der Canarischen Inseln, S. 206, 218, 248, and 289.

([420]) p. 286.—Barranco and barranca, both terms having the same meaning, and both in use in Spanish America, do indeed properly denote a water-furrow, a water-rift: "la quiebra que hacen en la tierra las corrientes de las aguas;"—"una torrente que hace barrancas;" they are, however, also employed for every kind of ravine. I doubt whether it is correct to connect the word with barro, "clay, soft moist mud, road mire."

([421]) p. 287.—Lyell, Manual of Elementary Geology, 1855, chap. xxix. p. 497. The most striking analogy with the phænomenon of the regular ribs in Java is presented by the surface of the mantle of the Somma at Vesuvius, on the seventy foldings of which much light has been thrown by an ingenious and exact observer, Julius Schmidt (Die Eruption des Vesuvs im Mai 1855, S. 101—109). In the view of Leopold von Buch these furrows were not originally made by the running down of rain-water (are not therefore "fiumare") but are rifts, as it were starred cracks, produced in the first upheaval of the volcano. The generally radial position of the lateral eruptions relatively to the axis of the volcano seems connected with this (S. 129).

([422]) p. 287.—"L'obsidienne et par conséquent les pierres-ponces sont aussi rares à Java que le trachyte lui-même. Un autre fait très-curieux c'est l'absence de toute coulée de lave dans cette île volcanique. M. Reinwardt, qui lui-même a observé un grand nombre d'éruptions, dit expressément qu'on n'a jamais eu d'exemples que l'éruption la plus violente et la plus dévastatrice ait été accompagnée de laves." (Léop. de Buch, Description des Iles Canaries, p. 419.) In the specimens of the volcanic rocks of Java for which the Cabinet of Minerals at Berlin is indebted to Dr. Junghuhn, dioritic-trachytes, composed of oligoclase and hornblende, may be most clearly recognised at Burungagung, S. 255, of the Leidner-Catalogue; at Tjinas, S. 232, and from G. Parang, situated in the Batu-Gangi district. This is also identically the same formation as the dioritic-trachytes of the volcanoes of Orizaba and Toluca in Mexico, of the Island of Panaria, one of the Lipari Isles, and of Ægina in the Ægean Sea.

([423]) p. 287.— Junghuhn, Bd. ii. S. 309 and 314. The fiery stripes which were seen on G. Merapi were formed by streams of glowing scoriæ (" traînées de fragmens"), disconnected masses, which being erupted roll down on the same side, and being of very different weights, overtake and strike against each other in their rapid passage down the abrupt descent. In the eruption of G. Lamongan, on the 26th of March 1847, such a stream divided into two branches some hundred feet below its origin. Junghuhn says expressly (Bd. ii. S. 767), that the fiery streaks consisted not of true molten lava, but of crowded fragments rolling down after each other. G. Lamongan and G. Semeru (the first, 5340, and the second, 12,235 feet high) are, among the volcanoes of Java, those which, by their activity during long periods, most nearly resemble Stromboli, which is scarcely 2960 feet high. The ejections of scoriæ occurred in G. Lamongan (in the eruptions of July 1838 and March 1847) after pauses of fifteen or twenty minutes ; and in G. Semeru (in the eruptions of August 1836 and September 1844) after pauses of from one and a half to three hours. (Bd. ii. S. 554 and 765—769.) In Stromboli itself, besides numerous eruptions of scoriæ, there are small and rare outpourings of lava which, being detained by obstacles, sometimes become hardened on the slope of the cone. I attach great importance to the different forms of continuity (as in lavas) or of disconnection (as in detached scoriæ) of the wholly or half fused materials which are ejected or poured out, either from the same or from different volcanoes. Analogous researches, conducted under the guidance of "leading ideas" in various regions of the globe, are much to be desired, in order to remedy the partial views which arise from the contemplation being limited to the four European active volcanoes. The question proposed by myself in 1802, and by my friend Boussingault in 1831, whether the Volcano Antisana, in the Cordillera of Quito, had sent forth streams of lava, which will be further touched upon, may perhaps find its solution in peculiarities to which fluid lava streams are subject. The essential character of a stream of lava is that of a uniform connected fluid, a band-like current, from which, as it cools and solidifies, scales detach themselves at the surface. These scales, beneath which the almost homogeneous lava long continues to flow, become pushed up, either obliquely or vertically, by the inequality of the internal movement and by the development of hot gases ; and thus, when several lava streams have flowed together into a kind of lava lake, as in Iceland, there is produced, after cooling, a " field of fragments." The Spaniards, especially in Mexico, call such spaces, which are very inconvenient to pass over, " Malpais." Such fields of lava fragments, which are often met with on the plain at the foot of a volcano, remind us of a lake of which the frozen surface has been broken up into blocks of ice.

([424]) p. 287.— The name G. Idjen may, according to Buschmann, be derived from the Javanese word hidjen: single, alone ; itself a derivative from the substantive hidji or widji: a "grain," or "seed," which combined with sa expresses the number one. On the etymology of Tengger, see my brother's comprehensive Notice, "Ueber die Verbindungen zwischen Java und Indien" (Kawi-Sprache, Bd. i. S. 188), where the historic importance of the Tengger mountains is shown as being inhabited by a small tribe who have retained their ancient Indo-Javanese belief, in opposition to the Mahometanism which now prevails generally over the island. Junghuhn, who is very diligent in explaining the mountain names from the Kawi language, says (Th. ii. S. 554) that "tengger" means "hill," as is also said in Gericke's Javanese Dictionary (Javaansch-Nederduitsch Woordenboek, Amst. 1847). Slamat, the name of the high volcano of Tegal, is the known Arabic word selamat, which means good speed, good success, hail.

([425]) p. 287.—Junghuhn, Bd. ii. : Selamat, S. 153 and 163 ; Idjen, S. 698 ; Tengger, S. 773.

([426]) p. 287.—Bd. ii. S. 760—762.

([427]) p. 289.—Atlas Géographique et Physique, accompanying the Rel. Hist. (1814) Pl. 28 and 29.

([428]) p. 289.—Kosmos, Bd. iv. S. 311—313 (English edition, p. 267—269).

([429]) p. 290.—Kosmos, Bd. i. S. 216 and 444 (English edition, p. 196 and Note 187), Bd. iv. S. 226 (English edition, p. 177).

([430]) p. 291.— In my Essai Politique sur la Nouvelle Espagne, in the two editions of 1811 and 1827 (in the latter, t. ii. p. 165—175), I gave, as the nature of the work required, only an abridged extract from my Journal, without the topographical plan or map of elevations. From the importance attached to such an event in the middle of the last century, I have thought it well to complete the extract for the present occasion. I am indebted for additional particulars respecting the new Volcano of Jorullo to an official document (written only three weeks after the day of the first eruption), which was first discovered in 1830 by a scientifically well-informed Mexican ecclesiastic, Don Juan José Pastor Moralès. Some of my information was derived from verbal communications made to me by my companion Don Ramon Espelde, who had obtained the information himself from surviving eye-witnesses of the event. Moralès discovered in the archives of the bishop of Michuacan a Report addressed by Joaquin de Ansogorri, priest in the Indian village of la Guacana, to his bishop, dated 19 Oct. 1759. Oberbergrath Burkart, in his instructive work entitled Aufenthalt und Reisen in Mexico (1336), has also given a short extract from it (Bd. i. S. 230). At the time of my journey, Don Ramon Espelde was living on the plain of Jorullo, and

had the merit of having been the first to ascend to the summit of the volcano. Some years later he joined the expedition made thither by the Intendente Corregidor Don Juan Antonio de Riaño, on the 10th of March 1789, to which belonged also a well-informed German, Franz Fischer, who had entered the Spanish service as commissary of mines. It was through Fischer that the name of Jorullo was first mentioned in Germany, by a letter which was printed in the Schriften der Gesellschaft der Bergbaukunde, Bd. ii. S. 441. But the rise of the new volcano had been spoken of still earlier, in Italy, in Clavigero's Storia Antica del Messico (Cesena, 1780, t. i. p. 42), and in the poetic work Rusticatio Mexicana of Pater Raphael Landivar (ed. altera, Bologna, 1782, p. 17). Clavigero, in his estimable work, erroneously places the rise of the new volcano (of which he writes the name Juruyo) in the year 1760, and enlarges his description by accounts of showers of ashes extending as far as Queretaro, which had been given him in 1766 by Don Juan Manuel de Bustamante, governor of the Province of Valladolid de Michuacan, as himself an eye-witness of the phænomenon. Landivar, who, like Ovid, was an enthusiastic adherent of our theory of upheaval, in well-sounding hexameters makes the colossus rise to the full height of three milliaria, and the thermal springs flow "cold by day and warm by night." However, I myself saw the centigrade thermometer rise to 52½° (126°·5 Fahr.) in the water of the Rio Cuitimba, at noon.

Antonio de Alcedo, in the 5th part of his great and useful Diccionario Geografico-Historico de las Indias Occidentales ó America, 1789,—therefore in the same year in which the Report of Riaño and Fischer appeared in the Gazeta de Mexico,—gave in the article Xurullo (p. 374—375) the interesting notice, that when the earthquakes began in the Playas (29 June 1759), the Volcano of Colima which was then in eruption was suddenly quieted, "although it is seventy leguas (as Alcedo says; according to my map only 112 geogr. miles) from the Playas." He adds, "It is supposed that the matter in the bowels of the earth met with obstacles to its continuing its former course, and at the same time found openings towards the east, and thus was diverted—para reventar en Xurullo" Exact topographical data for the neighbourhood of the volcano are also to be found in Juan José Martinez de Lejarza's Analisis Estadistico de la Provincia de Michuacan, en 1822 (Mexico, 1824, p. 125, 129, 130, and 131). The statement of the Author, who resided not far from Jorullo, that since my visit the mountain had shown no sign of increased volcanic activity, was first contradicted by reports of a new outbreak in 1819. (Lyell, Principles of Geology, 1855, p. 430.) As the position of Jorullo in latitude is not without importance, my attention has been drawn to the circumstance that Lejarza, who elsewhere always follows my determinations of latitude and longitude, and gives the lon-

gitude of Jorullo as I do, 2° 25′ W. of Mexico (101° 29′ W. of Greenwich), differs from me in the latitude. Is his latitude for Jorullo (18° 53′ 30″), which comes very near to that of Popocatepetl (18° 59′ 47″), founded on later observations with which I am unacquainted? In my Recueil d'Observations Astronomiques, vol. ii. p. 521, I have said expressly, "Latitude *supposée*, 19° 8′, derived from good star observations at Valladolid, which gave 19° 52′ 8″, and from the Itinerary direction." I only subsequently recognised the importance of the latitude of Jorullo when I was laying down the large Map of Mexico, and entering upon it the volcanic chain which runs east and west.

As in these considerations on the origin of Jorullo I have repeatedly alluded to traditionary stories still prevalent in the country, I will refer at the end of this long note to what is still a very popular tale, which was alluded to by me in another work (Essai Pol. sur la Nouv. Espagne, t. ii. 1827, p. 172): "Selon la crédulité des indigènes, ces changemens extraordinaires que nous venons de décrire sont l'ouvrage des moines. . . . . Aux *Playas de Jorullo*, dans la chaumière que nous habitions, notre hôte indien nous raconta qu'en 1759 des Capucins en mission prêchèrent à l'habitation de San Pedro, mais que, n'ayant pas trouvé un accueil favorable, ils chargèrent cette plaine, alors si belle et si fertile, des imprécations les plus horribles et les plus compliquées; ils prophétisèrent que d'abord l'habitation seroit engloutie par des flammes qui sortiroient de la terre, et que plus tard l'air ambiant se refroidiroit à tel point que les montagnes voisines resteroient éternellement couvertes de neige et de glace. La première de ces malédictions ayant eu des suites si funestes, le bas peuple indien voit déjà dans le refroidissement progressif du volcan le présage d'un hiver perpétuel."

The first printed account of the catastrophe (next to the poetical one of Landivar) was no doubt that already referred to in the Gazeta de Mexico, de 5 de Mayo 1789 (t. iii. Num. 30, p. 293—297). It had the modest heading: "Superficial y nada facultativa Descripcion del estado en que se hallaba el Volcan de *Jorullo*, la mañana del dia 10 de Marzo de 1789;" and was occasioned by the expedition of Riaño, Franz Fischer, and Espelde. Later, in 1791, the botanist Mociño and Don Martin Sesse, from the Nautico-Astronomical Expedition of Malaspina, visited Jorullo from the Pacific coast.

([431]) p. 295.—My barometric measurements give: for Mexico, 7469 feet; Valladolid, 6407 feet; Patzcuaro, 7225 feet; Ario, 6353 feet; Aguasarco, 4988 feet; and for the old plain of the Playas de Jorullo, 2583 feet. (Humb. Observ. Astron. vol. i. p. 327; Nivellement barométrique, No. 367—370.)

([432]) p. 295.—I find, taking the old level of the Playas at 404 toises (2583 feet): for the convexity of the Malpais, 3114 feet; for the crest of the great

lava stream, 3837 feet; for the highest margin of the crater, 4265 feet; and for the lowest point of the crater on which we could set up the barometer, 4118 feet. We thus obtained for the height of the summit of Jorullo above the ancient plain 1682 feet.

(433) p. 296.—Burkart, Aufenthalt und Reisen in Mexico, in den Jahren 1825—1834, Bd. i. (1836) S. 227.

(434) p. 296.—Burkart, Aufenthal, &c. Bd. i. S. 227 and 230.

(435) p. 296.—Poulett Scrope, Considerations on Volcanos, p. 267; Sir Charles Lyell, Principles of Geology, 1853, p. 429; Manual of Geology, 1855, p. 580; Daubeny on Volcanos, p. 337. Compare also, on the "elevation hypothesis," Dana, Geology, in the Account of the United States Exploring Expedition, vol. x. p. 369; and Constant Prevost, in the Comptes Rendus, t. xli. (1855), p. 866—876 and 918-923, sur les éruptions, &c. Compare also, on the subject of Jorullo, Carl Pieschel's instructive description of the volcanoes of Mexico, with elucidations by Dr. Gumprecht, in the Zeitschrift für Allg. Erdkunde of the Geographical Society of Berlin, Bd. vi. S. 490—517; and the recently published picturesque views in Pieschel's Atlas der Vulkane der Republik Mexico, 1856, Tab. 13, 14, and 15. The Royal Museum at Berlin possesses in the department of copperplate engravings and drawings a very fine and numerous collection of views of Mexican volcanoes (more than forty sheets), taken from nature by Moritz Rugendas. Of one volcano only, that of Colima, the westernmost of the Mexican volcanoes, this great master has given fifteen coloured views.

(436) p. 300.—"Nous avons été, M. Bonpland et moi, étonnés surtout de trouver, enchassés dans les laves basaltiques, lithoïdes et scorifiées du Volcan de Jorullo, des fragmens anguleux blancs ou blancs-verdâtres de *syénite*, composés de peu d'amphibole et de beaucoup de feldspath lamelleux. Là où ces masses ont été crevassées par la chaleur, le feldspath est devenu filandreux, de sorte que les bords de la fente sont réunis dans quelques endroits par des fibres allongées de la masse. Dans les Cordillères de l'Amérique du Sud, entre Popayan et Almaguer, au pied du *Cerro Broncoso*, j'ai trouvé de véritables fragmens de *gneiss* enchassés dans un trachyte abondant en pyroxène. Ces phénomènes prouvent que les formations trachytiques sont sorties au-dessous de la croûte granitique du globe. Des phénomènes analogues présentent les trachytes du *Siebengebirge* sur les bords du Rhin et les couches inférieures du phonolithe (*Porphyr-Schiefer*) du *Biliner-Stein* en Bohême." (Humboldt, Essai géognostique sur le Gisement des Roches, 1823, p. 133 and 339.) Burkart (Aufenthalt und Reisen in Mexico, Bd. i. S. 230) recognised also, imbedded in the black oliviniferous lava of Jorullo, "blocks of an altered syenite: hornblende is only seldom distinctly recognisable. The blocks of syenite would seem to offer irre-

fragable proof of the site of the fiery hearth of the volcano of Jorullo having been in or below the syenite, which shows itself at the surface for some considerable extent, a few leagues to the southward, on the left bank of the Rio de las Balsas which flows into the Pacific." In Lipari, near Caneto, Dolomieu, and, in 1832, the excellent geognost Friedrich Hoffmann even found in hard masses of obsidian enclosed fragments of granite formed out of pale-red feldspar, black mica, and a little light-gray quartz. (Poggendorf's Annalen der Physik, Bd. xxvi. S. 49.)

([437]) p. 302.—Strabo, lib. xiii. p. 579 and 628 ; Hamilton, Researches in Asia Minor, vol. ii. chap. 39. The westernmost of the three cones, now called Kara Devlit, is 530 feet above the plain, and has poured out a great stream of lava towards Koula. Hamilton counted above thirty small cones in the neighbourhood. The three orifices or abysses (*βόθροι* and *φῦσαι* of Strabo) are craters on conical mounts composed of scoriæ and lavas.

([438]) p. 302.—Erman, Reise um die Erde, Bd. iii. S. 538 ; Kosmos, Bd. iv. Anm. 25 (English edition, Note 349). Postels (Voyage autour du Monde, par le Cap. Lutké, Partie Hist. t. iii. p. 76) and Leopold von Buch (Description physique des Iles Canaries, p. 448) speak of the resemblance to the Hornitos of Jorullo. Erman, in a manuscript which he kindly communicated to me, describes a great number of truncated cones of scoriæ in the enormous lava field east of the Baidar mountains in the peninsula of Kamtschatka.

([439]) p. 304.—Porzio, Opera omnia, Med., Phil., et Mathem., in unum collecta, 1736 ; according to Dufrénoy, Mémoires pour servir à une Description géologique de la France, t. iv. p. 274. In the 9th edition of Sir Charles Lyell's Principles of Geology, 1853, p. 369, all genetic questions are treated with great fullness and praiseworthy impartiality. So long ago as 1749, Bouguer (Figure de la Terre, 1749, p. lxvi.) was not averse from the idea of the volcano of Pichincha having been upheaved : " Il n'est pas impossible que le rocher, qui est brûlé et noir, ait été soulevé par l'action du feu souterrain." Compare also p. xci.

([440]) p. 304.—Zeitschrift für allgemeine Erdkunde, Bd. iv. S. 398.

([441]) p. 304.—For the more certain determination of the minerals composing the Mexican volcanoes, older and more recent collections made by myself and by Pieschel have been compared.

([442]) p. 305.—The fine marble of la Puebla comes from the quarries of Tecali, Totomehuacan, and Portachuelo, south of the high trachytic mountain el Pizarro: also near the terrace-pyramid of Cholula, on the road to la Puebla, I have seen limestone crop out.

([443]) p. 306.—The Cofre de Pérote, to the south-east of the Fuerte or Castillo

de Pérote, near the eastern declivity of the great plateau of Mexico, stands almost alone, but yet its great mass belongs to an important line of heights which, forming the margin of the declivity, extends from Cruz Blanca and Rio Frio towards las Vigas (N. lat. 19° 37′ 37″), passing the Cofre de Pérote (N. lat. 19° 29′, W. long. 97° 08′), west of Xicochimalco and Achilchotla, to the Peak of Orizaba (N. lat. 19° 2′, W. long. 97° 14′) in a north and south direction parallel to the chain (Popocatepetl-Iztaccihuatl) which divides the valley of the Mexican lakes from the plain of la Puebla. (For the bases of these determinations, see my Recueil d'Observ. Astron. vol. ii. p. 529—532, and 547, as well as my Analyse de l'Atlas du Mexique, and Essai Pol. sur la Nouv. Espagne, t. i. p. 55—60.) As the Cofre has been elevated so as to rise abruptly in a pumice-covered space many miles in breadth, it appeared to me exceedingly interesting that when I ascended the mountain in the winter, on the 7th Feb. 1804, on the summit the thermometer sank to 28°·4; the covering of pumice, of which I measured the height and thickness barometrically at several points, both in ascending and descending, was found by me to rise above 780 feet. The lower limit of the pumice in the plain between Pérote and Rio Frio is 7590 feet above the level of the sea, the upper limit on the northern declivity, 8370 feet; and from thence through the Pinahuast, the Alto de los Caxones (12,495 feet high), where I was able to determine the latitude by the sun's meridian altitude, to the summit itself, there was no trace of pumice to be seen. When the mountain was elevated it must have carried with it a portion of the pumice-covering of the great Arenal, on which it had perhaps been made a smooth flat surface by water. When on the spot, in February 1804, I made a drawing of this pumice-covered zone in my journal. It is the same important phænomenon as that described in 1834 by Von Buch at Vesuvius, where horizontal strata of pumice-tufa have been carried up to a greater height (1900 or 2000 feet), about the Hermitage del Salvatore. (Poggendorff's Annalen, Bd. xxxvii. S. 175—179.) The surface of the dioritic-trachyte rock at the Cofre was not concealed from observation by snow at the part where I found the pumice highest up on the mountain. In Mexico, in lat. 19° and 19¼°, the limit of perpetual snow is on an average about 14,760 feet high; and the summit of the mountain, at the foot of the small house-like cubical rock where I set up the instruments, is 13,416 feet above the sea. By measurement of angles the cube of rock is 134 feet high, making the absolute summit, which could not be reached on account of this last vertical precipice, 13,550 feet. I found only some patches of sporadically fallen snow, of which the lower limit was 12,150 feet above the sea, fully 700 or 800 feet below the upper limit of forest trees, being fine trees of Pinus occidentalis interspersed with Cupressus sabinoides and Arbutus madroño. The

oak Quercus xalapensis had only accompanied us to 10,338 feet of absolute height. (Humboldt, Nivellement barométr. des Cordillères, No. 414—429.) The name Nauhcampatepetl, which the mountain bears in the Mexican language, is taken from the same peculiarity of shape which led the Spaniards to give it the name of Cofre. Nauhcampa, formed from nahui, the number four, no doubt means four-sided, or quadrangular. Pieschel conjectures the existence of an ancient crater-orifice on the eastern declivity of the Cofre of Pérote. (Zeitschr. für allg. Erdkunde, herausg. von Gumprecht, Bd. v. S. 125.) The view of the Cofre in my Vues des Cordillères, Pl. XXXIV, was taken by me from near the Castle San Carlos de Pérote, about eight miles distant. The old Aztec name of Pérote was Penahuizapan, signifying, according to Buschmann, a kind of chafer pinahuiztli (regarded as ill-omened and employed in superstitious augury ; compare Sahagun, Historia gen. de las Cosas de Nueva España, t. ii. 1829, p. 10—11), a name derived from pinahua, "to be ashamed." From the same verb comes the above-mentioned name of a district, Pinahuast (pinahuaztli), as well as the name of a shrub (? a Mimosa), pinahuihuiztli, translated by Hernandez herba verecunda, the leaves of which droop on being touched.

([414]) p. 308.—Strabo, lib. i. p. 58, lib. vi. p. 269, Casaub ; Kosmos, Bd. i. S. 451 (English edition, Note 225), and Bd. iv. S. 270, and, on the Greek name for lava, Anm. 82 (English edition, Note 306).

([415]) p. 308.—Kosmos, Bd. iv. S. 310 and Anm. 68 (English edition, Note 392).

([416]) p. 308.—La Condamine says : "Je n'ai point connu la matière de la lave en Amérique, quoique nous ayons, M. Bouguer et moi, campé des semaines et des mois entiers sur les volcans, et nommément sur ceux de Pichincha, de Cotopaxi et de Chimborazo. Je n'ai vu sur ces montagnes que des vestiges de calcination sans liquéfaction. Cependant l'espèce de crystal noirâtre appelé vulgairement au Pérou *Piedra de Gallenaço* (obsidienne), dont j'ai rapporté plusieurs morceaux et dont on voit une lentille polie de sept à huit pouces de diamètre au Cabinet du Jardin du Roi, n'est autre chose qu'un verre formé par les volcans. La matière du torrent de feu qui découle continuellement de celui de Sangai dans la province de Macas, au sud-est de Quito, est sans doute une lave ; mais nous n'avons vu cette montagne que de loin, et je n'étois plus à Quito dans le temps des dernières éruptions du volcan de Cotopaxi, lorsque sur ses flancs il s'ouvrit des espèces de soupiraux, d'où l'on vit sortir à flots des matières enflammées et liquides qui devoient être d'une nature semblable à la lave du Vésuve." (La Condamine, Journal de Voyage en Italie, in the Mémoires de l'Académie des Sciences, Année 1757, p. 357 ; Histoire, p. 12.) These two examples, especially the first, are not happily chosen. Sangay was first scientifically exa-

mined by Sebastian Wisse in December 1849. What La Condamine, at a distance of 108 geographical miles, took for glowing lava, and even for an outpouring of burning sulphur and petroleum, were glowing rocks and masses of scoriæ following each other closely down the steep descent. (Kosmos, Bd. iv. S. 303 (English edition, p. 258.) I have not seen on the Cotopaxi, any more than on Tungarahua, Chimborazo, Pichincha, or on the Puracé and Sotara near Popayan, anything which could be regarded as narrow currents of lava having flowed from those giant-mountains. The unconnected glowing masses of five or six feet diameter, often containing obsidian, which have been ejected in eruptions of Cotopaxi, have been carried by floods of melted snow and ice to far into the plain, and these form partially radiating diverging lines. Elsewhere, La Condamine also says very truly: " Ces éclats de rocher, gros comme une chaumière d'Indien, forment des traînées de rayons qui partent du volcan comme d'un centre commun." (Journal du Voyage à l'Equateur, p. 160.)

(447) p. 309.—Guettard's Memoir on extinct volcanoes was read at the Academy in 1752, therefore three years before La Condamine's journey to Italy, but it was not printed until 1756 during that visit. (See p. 380.)

(448) p. 313. — " Il y a peu de volcans dans la chaîne des Andes (said Von Buch) qui aient offert des courants de laves, et jamais on n'en a vu autour des volcans de Quito. L'Antisana, sur la chaîne orientale des Andes, est le seul volcan de Quito sur lequel M. de Humboldt ait vu près du sommet quelque chose d'analogue à un courant de laves ; cette coulée était tout-à-fait semblant à de l'obsidienne." (Descr. des Iles Canaries, 1836, p. 468 and 488.)

(449) p. 315.—Humboldt, Kleinere Schriften, Bd. i. S. 161.

(450) p. 316.—" Nous différons entièrement sur la prétendue coulée d'Antisana vers Pinantura. Je considère cette coulée comme un soulèvement récent analogue à ceux de Calpi (Yana Urcu), Pisque et Jorullo. Les fragmens trachytiques ont pris une épaisseur plus considérable vers le milieu de la coulée. Leur couche est plus épaisse vers Pinantura que sur des points plus rapprochés d'Antisana. L'état fragmentaire est un effet du soulèvement local, et souvent dans la Cordillère des Andes les tremblements de terre peuvent être produits par des *tassements*." (Lettre de M. Boussingault, en août 1834.) Compare Kosmos, Bd. iv. S. 219 (English edition, p. 170). In the description of his ascent of Chimborazo (December 1831), Boussingault says: " The mass of the mountain consists, in my view, of an enormous heap of fragments of trachyte piled up on each other without any order. These fragments of a volcano, often of enormous size, were elevated in a solid state, their edges are sharp and nothing indicates a state of fusion or even of softening. Nowhere is there observed on any of the equatorial volcanoes anything from which a stream of lava

could be inferred. Nothing has ever been ejected from these craters but masses of mud, elastic fluids, and glowing, more or less scorified, blocks of trachyte which are often thrown to considerable distances." (Humboldt, Kleinere Schriften, Bd. i. S. 200.) On the first origin of the opinion of the upheaval of accumulations of solid masses, see Acosta in the Viajes á los Andes ecuatoriales, por M. Boussingault, 1849, p. 222 and 223. In the opinion of this celebrated traveller, the movements caused among these fragments by earthquake shocks and other causes, and the gradual filling up the intervals between them must occasion a gradual lowering of the heights of the mountains.

([451]) p. 316.—Humboldt, Asie Centrale, t. ii. p. 296—301. (Gustav Rose, Mineral-geognostische Reise nach dem Ural, dem Altai und dem Kasp. Meere, Bd. i. S. 599.) Long narrow walls or dykes of granite may have been raised up over fissures in the earliest foldings of the earth's crust, analogous to those remarkable ones which remain still open, which are found at the foot of the volcano of Pichincha; the "Guaycos" of the city of Quito, thirty or forty feet broad. (See my Kl. Schr., Bd. i. S. 24.)

([452]) p. 316.— La Condamine, Mesure des trois premiers degrés du Méridien dans l'Hémisphère Austral, 1751, p. 56.

([453]) p. 317.—Neither Passuchoa, nor Atacazo, between which the Hacienda el Tambillo intervenes, enters the limits of perpetual snow. The high margin of the crater, la Peila, has fallen in on the western side, but shows itself on the eastern as an amphitheatre. It is said in the country that, near the end of the sixteenth century, Passuchoa which had been previously active ceased to be so on the occasion of an eruption of Pichincha, and that the cessation has been absolute and perpetual : confirming the existence of inter-communication between the opposite Eastern and Western Cordilleras. The proper basin of Quito, closed in as by walls, towards the north by a mountain-knot between Cotocachi and Imbaburo, towards the south by the Altos de Chisinche (between 0° 20′ N. and 0° 40′ S. lat.), is for the greater part of its length divided in two by the ridge of Ichimbio and Poingasi. To the east is the valley of Puembo and Chillo, and to the west the plain of Iñaquito and Turubamba. Proceeding from north to south we have successively, in the Eastern Cordillera—Imbaburo, the Faldas de Guamani, and Antisana, Sinchulahua, and the perpendicular black wall, crowned with tower-like elevations, of Rumiñaui (stone-eye) ; and, in the Western Cordillera—Cotocachi, Casitagua, Pichincha, Atacazo, and Corazon, on the slopes of which the magnificent Alpine flower, the red Ranunculus Gusmani, flourishes. It has seemed to me suitable to give here, from personal observations, a brief description of this important and classic ground for volcanic geology.

([454]) p. 319.—It is particularly striking that the great volcano Cotopaxi which (for the most part indeed only after long intervals of repose) manifests enormous activity, especially by the devastating inundations which it causes, yet in the intervals between these outbursts shows no visible smoke or vapour, as seen either from the Paramo de Pansache or from the high plain of Lactagunga. Comparison with other equally lofty volcanoes shows that this absence is not to be explained from the rarity of the air and of the vapour at the great elevation of 19,000 feet. None of the other Nevados in the equatorial Cordilleras are so often seen in cloudless grandeur and beauty as the truncated cone of Cotopaxi, *i. e.* the portion which rises above perpetual snow. Its uninterrupted regularity of form much exceeds that of the Peak of Teneriffe, in which a narrow projecting wall-like ridge of obsidian runs down from the cone. The upper portion of Tungurahua may have been once almost as distinguished by regularity of form as Cotopaxi, but it is now greatly disfigured by the effects of the great earthquake of the 4th February 1797, called the catastrophe of Riobamba, by which it was crevassed; parts fell in, others glided down, carrying with them the forests which clothed them, and large accumulations of debris were formed. On Cotopaxi, as Bouguer had already remarked, there are points at which pumice and snow are intermingled, and almost form one solid mass. A little unevenness in the snowy mantle can be discovered on the north-west side, where two cleft-like valleys run down. One does not see from a distance anything of black rocky ridges running up towards the summit, although, in the eruptions of the 24th June and 9th December 1742, a lateral opening showed itself half-way up the snow-covered cone of cinders. "Il s'étoit ouvert une nouvelle bouche vers le milieu de la partie continuellement neigée, pendant que la flamme sortoit toujours par le haut du cône tronqué. (Bouguer, in Figure de la Terre, p. lxviii. Compare also La Condamine, Journ. du Voy. à l'Equateur, p. 159.) It is only quite near to the summit that one perceives some horizontal, parallel, but interrupted black streaks. Looked at through the telescope under different incidences of light they appear to me to be ridges of rock. This whole upper part is steeper than the rest of the mountain, and forms, almost close to the truncation of the cone, a wall-like annular ridge of unequal height, not, however, visible to the naked eye by reason of the great distance. My description of this highest, almost perpendicular, encircling ridge strongly drew the attention of two distinguished geologists, Darwin (Volcanic Islands, 1844, p. 83) and Dana (Geology of the U. S. Explor. Exped., 1849, p. 356). The volcanoes of the Galapagos islands, Diana's Peak in St. Helena, and Teneriffe, show analogous conformations. The highest point of Cotopaxi, of which I measured the elevation by angles, is in a black convexity. Perhaps it is the inner wall of a higher and more distant

crater margin; or is the snowlessness of the projecting rock occasioned both by steepness and by crater warmth? On one night, in the autumn of 1800, the whole upper part of the cone appeared luminous, without this being followed by any eruption or even by any visible emission of vapour. On the other hand, at the violent eruption, 4 Jan. 1803, when I was staying on the shores of the Pacific and saw the windows shake in the port of Guayaquil from the vibration caused by the thundering noise of the volcano 148 geographical miles distant, the cone entirely lost its snowy covering and wore a threatening aspect. Had such an effect been observed on any previous occasion? Very recently we have learnt from the lady who has wandered round the world with such admirable bravery, Madame Ida Pfeiffer (Meine zweite Weltreise, Bd. iii. S. 170), that in the early part of April 1854 an outburst took place in which Cotopaxi emitted thick columns of smoke "through which darted serpentine flames of fire." May the flames have been the lightnings of a volcanic tempest excited by evaporation? Eruptions have been frequent since 1851.

The great regularity of the snow-covered truncated cone itself renders still more striking the appearance, at the lower limit of the region of perpetual snow, where the conical form begins, of a small grotesquely jagged mass of rock, having three or four points. Probably by reason of its steepness, the snow lies on it only here and there in patches. A glance at my drawing (Atlas pittoresque du Voyage, Pl. X.) shows these relations more clearly. I approached this dark gray, probably basaltic, mass of rock most nearly in the Quebrada and Reventazon de Minas. Although for centuries this remarkable-looking mass has borne, throughout the province, the name of Cabeza del Inga, yet among the coloured inhabitants (the Indians) two very different hypotheses concerning its origin prevail; one simply asserts that this rock is the pointed top of the volcano which has fallen off, without assigning any time for the supposed event, which the other hypothesis places in the year (1533) in which the Inca Atahuallpa was strangled; thus connecting it both with the terrible fiery eruptions of Cotopaxi which ensued in the same year, and have been described by Herrera, and also with the oracular predictions of Huayna Capac, Atahuallpa's father, on the approaching fall of the Peruvian empire. It may be asked whether the one thing common to these two hypotheses, the supposition that the "Cabeza del Inga" once formed the summit of the cone, may not indicate an obscure remembrance of a real event, which might be thus preserved, though without any apprehension of geological ideas. I altogether doubt the correctness of this view. The idea of a truncated cone having "lost its top," and of this top having been thrown to a distance unbroken, just as large masses of rock are seen to be hurled afar in recent eruptions, is one which presents itself not unnaturally to even very un-

educated minds. The terraced pyramid of Cholula, an artificial erection of the Toltecs, is truncated: the natives, from the impression that it must have been originally a complete pyramid, have imagined the fable that its top was destroyed by a stone which fell on it from heaven, and even assert that fragments of this aerolite were shown to the Spanish Conquistadores. How would it be possible to place the first eruption of Cotopaxi at a time when the cone of cinders (the result of a series of eruptions) is admitted, in the story itself, to have been already existing? It seems to me probable that the Cabeza del Inga originated at the spot where it now is: like Yana-Urcu at the foot of Chimborazo, and — on Cotopaxi itself — the "Morro," south of Sunniguaicu, and north-west of the little lake Yurak-cocha (white lake in the Qquechhua language).

Respecting the name of Cotopaxi, I have said, in the first volume of my Kleinere Schriften (S. 463), that it is only the first part of the word which can be interpreted in the Qquechhua language, in which "ccotto" means "heap," but that "pacsi" is quite unknown. La Condamine (p. 53) interprets the entire name of the mountain, saying: "le nom signifie en langue des Incas *masse brillante*." Buschmann, however, remarks that this requires the substitution for pacsi of pacsa (which is certainly not the same word), meaning brightness, shining, especially the soft brightness of the moonshine; but, in order to express the idea of a "shining mass," the genius of the language would further require the order of the two words to be reversed, "pacsacotto."

(455) p. 319. — Friedrich Hoffmann, in Poggendorff's Annalen, Bd. xxvi. 1832, S. 48.

(456) p. 320. — Bouguer, Figure de la Terre, p. lxviii. How often, since the earthquake of 19th July 1698, has the little town of Lactagunga been destroyed, and rebuilt out of blocks of pumice-stone from the subterranean quarries of Zumbalica! According to the historic documents, consisting of copies of old ones which had thus perished, and of some more recently saved, in partial rescues, from the town archives, it appears that such destructions took place in 1703, 1736, 9th Dec. 1742, 30th Nov. 1744, 22nd Feb. 1757, 10th Feb. 1766, and 4th April 1768: seven times in sixty-five years! In 1802, I still found four fifths of the town in ruins, the result of the great earthquake of Riobamba, 4th Feb. 1797.

(457) p. 321. — This diversity was also already recognised by the sagacious Abich (Ueber Natur und Zusammenhang vulkanischer Bildungen, 1841, S. 83).

(458) p. 321. — The rock of Cotopaxi has essentially the same mineralogical composition as the volcanoes which are nearest to it, Antisana and Tungurahua. It is a trachyte composed of oligoclase and augite, therefore a "Chimborazo-rock:" a proof of identity of the volcanic rock in the Cordilleras opposite to

each other. In the pieces collected by me in 1802, and by Boussingault in 1831, the mass is partly light or greenish grey, shining like pitchstone, and translucent at the edges; and partly black, almost like basalt, with great and small pores with shining sides. The oligoclase sharply defined is embedded in the mass; appearing sometimes very distinctly in shining crystals forming streaks in the planes of cleavage, and sometimes being very minute, and difficult to recognise. The interspersed augites, which belong essentially to the rock, are brownish and blackish green, and of very various sizes. Dark laminæ of mica, and black grains of magnetic iron of a metallic lustre, occur, but only rarely, and probably accidentally. In the pores of a piece in which there is much oligoclase there is some native sulphur, probably deposited from the all-pervading sulphurous vapours.

([459]) p. 322. — "Le Volcan de Maypo (lat. austr. 34° 15′), qui n'a jamais rejeté de ponces, est encore éloigné de deux journées de la colline de Tollo, de 300 pieds de hauteur, et toute composée de ponces qui renferment du feldspath vitreux, des cristaux bruns de mica, et de petits fragmens d'obsidienne. C'est donc une éruption (indépendante), isolée tout au pied des Andes et près de la plaine." (Léop. de Buch, Description physique des Iles Canaries, 1836, p. 470.)

([460]) p. 322. — Federico de Gerolt, Cartas geognosticas de los principales Distritos minerales de Mexico, 1827, p. 5.

([461]) p. 323. — Compare On the Solidification and Formation of the Earth's Crust, Kosmos, Bd. i. S. 178—180, and Anm. 7 on S. 425 (English edition, p. 161—163, and Note 137. The experiments of Bischof, Charles Deville, and Delesse have thrown a new light on the folding and crevassing of the earth's crust. Compare also the ingenious considerations of Babbage on the occasion of his thermic explanation of the problem presented by the temple of Serapis, on the north of Puzzuoli, in the Quarterly Journal of the Geological Society of London, vol. iii. 1847, p. 186; Charles Deville, Sur la Diminution de Densité dans les Roches en passant de l'Etat cristallin à l'Etat vitreux, in the Comptes Rendus de l'Acad. des Sciences, t. xx. 1845, p. 1453; Delesse, Sur les Effets de la Fusion, t. xxv. 1847, p. 545; Louis Frapolli, Sur le Caractère géologique, in the Bulletin de la Soc. Géol. de France, 2^{e} série, t. iv. 1847, p. 627; and above all, Elie de Beaumont, in his important work, Notice sur les Systèmes de Montagnes, 1852, t. iii. The following three sections deserve especial attention from geologists: "Considérations sur les soulèvements dûs à une diminution lente et progressive du volume de la Terre, p. 1330; Sur *l'écrasement transversal*, nommé *refoulement* par Saussure, comme une des causes de l'élévation des chaînes de montagnes, p. 1317, 1333, and 1346; Sur la contraction que les roches fondues éprouvent en cristallisant, tendant dès le commencement du

refroidissement du globe à rendre sa masse interne plus petite que la capacité de son enveloppe extérieure, p. 1235.

([462]) p. 324. — " Les eaux chaudes de Saragyn, à la hauteur de 5260 pieds, sont remarquables par le rôle que joue le gaz acide carbonique qui les traverse à l'époque des tremblements de terre. Le gaz à cette époque, comme l'hydrogène carboné de la presqu'île d'Apchéron, augmente de volume, et s'échauffe avant et pendant les tremblements de terre dans la plaine d'Ardébil. Dans la presqu'île d'Apchéron la temperature s'élève de 20° jusqu'à l'inflammation spontanée au moment et à l'endroit d'une éruption ignée, pronostiquée toujours par des tremblements de terre dans les provinces de Chémakhi et d'Apchéron." (Abich, in the Mélanges physiques et chimiques, t. ii. 1855, p. 364 and 365.) (Compare Kosmos, Bd. iv. S. 223; English edition, p. 175.)

([463]) p. 324. — W. Hopkins, Researches on Physical Geology, in the Phil. Trans. for 1839, Pt. II. p. 311; for 1840, Pt. I. p. 193; and for 1842, Pt. I. p. 43; and also On the requisite Conditions of Stability of the exterior Surface of the Earth, in the Theory of Volcanoes in the Report of the Seventeenth Meeting of the British Association, 1847, p. 45—49.

([464]) p. 324. — Kosmos, Bd. iv. S. 35—38, Anm. 33—36 (English edition, Notes 33—36); Naumann, Geognosie, Bd. i. S. 66—76; Bischof, Wärmelehre, S. 382; Lyell, Principles of Geology, 1853, p. 536 to 547, and 562. In the very instructive and pleasant work, Souvenirs d'un Naturaliste, par A. de Quatrefages, 1854, t. ii. p. 464, the upper limit of the fluid molten strata is brought up to the small depth of 20 kilomètres: " puisque la plupart des silicates fondent déjà à 666° cent." Gustav Rose remarks that " this low estimate is based on an error. The temperature of 1300° cent., which Mitscherlich gives as the melting point of granite (Kosmos, Bd. i. S. 48; English edition, p. 27, and Note 13), is certainly the least that can be taken. I have several times had granite put into the hottest parts of the porcelain furnace, and it has always been but imperfectly fused. Only the mica is fused, with the felspar forming a glass with many bubbles; the quartz becomes opaque, but does not fuse. It is the same with all kinds of rock which contain quartz, and, indeed, this may be used as a test for discovering quartz in rocks in which it exists in quantities so small as not to be discernible by the naked eye, ex. gr. in the Plauen syenite and in the diorite which we brought back with us, in 1829, from Alapajewsk in the Ural. All rocks which do not contain any quartz, or any minerals containing as much silica as does granite (for example basalt), when exposed to the same heat as porcelain, fuse more easily than granite into a perfect glass; but they do not do this over a spirit lamp with a double current of air, which yet is certainly capable of affording a temperature of 666° cent." In

Bischof's remarkable experiments in casting a ball of basalt, that substance appeared, according to some hypothetical assumptions, to require a temperature of 165° Réaumur higher than the melting point of copper. (Wärmelehre des Innern unsers Erdkörpers, S. 473.)

([465]) p. 326. — Kosmos, Bd. iv. S. 218 (English edition, p. 169). Compare also, respecting the unequal extension and depth of the icy soil, apart from latitude, the remarkable observations of Franklin, Erman, Kupffer, and, above all, Middendorff. Kosmos, Bd. iv. S. 43, 47, and 167 (English edition, p. 42—48, and Note 46).

([466]) p. 326. — Leibnitz, in the Protogæa, § 4.

([467]) p. 327. — On Vivarais and Velay, see the most recent and very exact researches of Girard, in his "Geologischen Wanderungen," Bd. i. (1856) S. 161, 173, and 214. The ancient volcanoes of Olot were discovered by the American geologist Maclure in 1808, visited by Lyell in 1830, and well described and represented by him in his Manual of Geology, 1855, p. 535—542.

([468]) p. 328. — Sir Rod. Murchison, Siluria, p. 20 and 55—58 (Lyell, Manual, p. 563).

([469]) p. 328. — Scoresby, Account of the Arctic Regions, vol. i. p. 155—169, Tab. V. and VI.

([470]) p. 329. — Léop. von Buch, Descr. des Iles Canaries, p. 357—369; and Landgrebe, Naturgeschichte der Vulkane, 1855, Bd. i. S. 121—136; and on the encircling ridges of the elevation-craters (caldeiras) in the islands of San Miguel, Fayal, and Terceira (according to the charts of Vidal), see Kosmos, Bd. iv. Anm. 84 zu S. 271 (English edition, Note 308). The eruptions of Fayal (1672) and S. Jorge (1580 and 1808) appear to depend on the principal volcano, that of Pico.

([471]) p. 329. — Kosmos, Bd. iv. S. 291 (Anm. 27) and 301 (English edition, 257).

([472]) p. 329. — Results of Observations on Madeira, by Sir Charles Lyell and Hartung, in the Manual of Geology, 1855, p. 515—525.

([473]) p. 330. — Darwin, Volcanic Islands, 1844, p. 23; and Lieut. Lee, Cruise of the U.S. Brig Dolphin, 1854, p. 80.

([474]) p. 330.—See the excellent description of Ascension by Darwin, Volcanic Islands, p. 40 and 41.

([475]) p. 330. — Darwin, p. 84 and 92, on "the great hollow space or valley southward of the central curved ridge, across which the half of the crater must once have extended. It is interesting to trace the steps, by which the structure of a volcanic district becomes obscured, and finally obliterated. (Compare also Seale, Geognosy of the Island of St. Helena, p. 28.)

(476) p. 331. — St. Paul's Rocks. See Darwin, p. 31—33 and 125.

(477) p. 331. — Daussy, Sur l'existence probable d'un Volcan sous-marin dans l'Atlantique, in the Comptes rendus de l'Acad. des Sciences, t. vi. 1838, p. 512; Darwin, Volcanic Islands, p. 92; Lee, Cruise of the U.S. Brig Dolphin, p. 2, 55, and 61.

(478) p. 332. — Gumprecht, Die vulkanische Thätigkeit auf dem Festlande von Afrika, in Arabien, und auf den Inseln des rothen Meeres, 1849, S. 18.

(479) p. 333. — Kosmos, Bd. i. S. 456, Anm. 7 (English edition, Note 237). On the totality of phænomena, so far as known to us in Africa, see Landgrebe, Naturgeschichte der Vulkane, Bd. i. S. 195—219.

(480) p. 334.—The height of Demavend above the sea is given by Ainsworth 14,695 feet; but after correcting a barometric result which probably rested on an accidental clerical error (Asie Centr. t. iii. p. 327), it comes, according to Oltmann's Tables, to fully 18,634 feet. A still greater height, 20,085 feet, is given by the doubtless very trustworthy angles of altitude of my friend Captain Lemm of the Russian Imperial Navy in 1839; but the distance does not rest on a trigonometric basis, but only on the assumption that the Volcano of Demavend is 66 versts (104·3 versts = an equatorial degree) from Teheran. It appears, according to this, that the Persian ever snow-clad Volcano of Demavend, situated so near the southern shore of the Caspian, and 600 geographical miles from the Colchian shore of the Black Sea, exceeds the great Ararat by 2984 (or about 3000 feet), and the Caucasian Elboruz by perhaps 1600 feet. On the Volcano of Demavend, see Ritter, Erdkunde von Asien, Bd. vi. Abth i. S. 551—571; and on the connection of the name Albordj, from the mythical and vague Zend geography, with the modern Elbourz (Koh Alburz of Kazwini) and Elburuz, S. 43, 49, 424, 552, and 555.

(481) p. 340.—Asie Centrale, t. ii. p. 9 and 54—58 (Kosmos, Bd. iv. S. 253, Anm. 61, English edition, Note 285).

(482) p. 340. — Elburuz, Kasbegk, and Ararat, according to communications from Struve. Asie Centr. t. ii. p. 57. The height given in the text for the extinct Volcano of Savalan, west of Ardebil, 15,760 English feet, rests on a measurement by Chanykow. See Abich, in the Mélanges phys. et chim. t. ii. p. 361. In order to avoid wearisome repetition as to the sources which I have drawn from, I will state here that all which in the geological section of the Kosmos relates to the important Caucasian isthmus is taken from writings of Abich, communicated to me in manuscript by him, 1852—1855, with the most generous and kind permission to make the freest use of them.

(483) p. 340. — Abich, Notice explicative d'une Vue de l'Ararat, in the Bulletin de la Soc. de Géographie de France, 4e série, t. i. p. 516.

([484]) p. 349. — Compare Dana's ingenious remarks "On the Curvatures of Ranges of Islands, whose Convexity, in the Pacific, is almost always turned to the south or south-east." U.S. Explor. Exped., by Wilkes, vol. x. (Geology by James Dana) 1849, p. 419.

([485]) p. 349.—The island Saghalin, Tschoka, or Tarakai, is called by Japanese sailors Krafto (written Karafuto). It lies opposite to the mouth of the Amur (the Black River, Saghalian Ula), and is inhabited by a good-humoured, dark-coloured, and sometimes rather hairy race. Admiral Krusenstern supposed, as did previously the companions of La Pérouse (1787), and Broughton (1797), that Saghalin is connected with the Asiatic continent by a narrow sandy isthmus (in 52° 5′ N. lat.) ; but we find among the important Japanese information obtained by Siebold, by a survey chart laid down in 1808 by Mamia Rinsô, chief of an Imperial Japanese commission, that Krafto is not a peninsula, but is surrounded by the sea on all sides (Ritter, Erkunde von Asien, Bd. iii. S. 488). This result of the meritorious Mamia Rinsô has been recently (1855) confirmed by the fact that the Russian fleet, in the Baie de Castries, at Alexandrowsk (lat. 51° 29′), therefore south of the supposed isthmus, were able to retreat into the mouth of the river (lat. 52° 54′) just as Siebold had said. In the strait, where the isthmus was supposed to be, there are at some points only five fathoms water. The island begins to be politically important on account of its vicinity to the Amur, or Saghalian River. The name pronounced Karafto or Krafto is a contraction of Kara-fu-to, i. e. according to Siebold, "the island adjacent to the Kara ;" Kara being a Japano-Chinese designation for the extreme north of China, Tartary, and "fu," "adjacent to." Tschoka is a corruption of Tsokai, and Tarakai is taken by a misunderstanding from the name of a single village, Taraika. According to Klaproth (Asia Polyglotta, p. 301) Taraikai, or Tarákai, is the native Eino name of the whole island. Compare Leopold Schrenk's and Captain Bernard Wittingham's remarks in Petermann's Geogr. Mittheilungen, 1856, S. 176 and 184 ; and also Perry, Exped. to Japan, vol. i. p. 468.

([486]) p. 350. — Dana, Geology of the Pacific Ocean, p. 16. The coasts of Cochinchina, from the bay of Tonquin ; those of Malacca, from the bay of Siam ; and even those of New Holland south of the twenty-fifth parallel also run nearly north and south.

([487]) p. 360.—Compare the translations of Stanislas Julien from the Japanese Encyclopedia in my Asie Centr. t. ii. p. 551.

([488]) p. 360.—Compare Kaart van den Zuid- en Zuidwest-kust van Japan, door F. von Siebold, 1851.

([489]) p. 361.—Compare my Fragmens de Géologie et de Climatologie asiatiques,

t. i. p. 82, which were published immediately after my return from the Siberian Expedition; as well as my Asie Centrale, in which I have combated the opinion expressed by Klaproth, which I had also myself previously entertained, and which was rendered probable by the connection of the snowy mountains of the Himalaya with the Chinese province of Yun-nan and the Nauling, north-west of Canton. The mountains of Formosa, which are more than 11,700 feet high, belong, as do the Ta-ju-ling which bound the Foo-kien on the west, to the same system of north and south fissures as those of Upper Assam in the Birman country, and the group of the Philippines.

([490]) p. 362.—Dana, Geology of the Explor. Exped. vol. x. p. 540—545; Ernst Hofmann, Geogn. Beob. auf der Reise von Otto v. Kotzebue, S. 70; Léop. de Buch, Descr. Phys. des Iles Canaries, p. 435—439. Compare Don Antonio Morati's large and excellent Chart of the Islas Filipinas (Madrid, 1852), in two sheets.

([491]) p. 362.—Marco Polo distinguishes (Part. III. cap. v. and viii.) Giava minore (Sumatra), where he staid five months, and where he describes the elephants, not found in Java (Humboldt, Examen crit. de l'Hist. de la Géogr. t. ii. p. 218), from the earlier-described Giava (maggiore), "la quale, secondo dicono i marinai, che bene lo sanno, è l' isola più grande che sia al mondo." This assertion is still true. According to the outlines of the coast of Borneo and Celebes by James Brooke and Capt. Rodney Mundy, I find the area of Borneo 12,920 (German geographical) square miles, only one tenth of the area of the continent of New Holland. Marco Polo's accounts of the "much gold and great riches which the mercanti di Zaiton e del Mangi bring from thence," show that he as well as Martin Behaim on the Nuremberg Globe of 1492, and Johann Ruysch in his Roman edition of Ptolemy of 1508 (so important for the history of the discovery of America), means by Java major, Borneo.

([492]) p. 363.—Captain Mundy's Chart (Coast of Borneo Proper, 1847) even gives 14,000 feet. For doubts respecting this elevation, see Junghuhn's Java, Bd. ii. S. 850. Kina Bailu is not a conical mountain; its form is much more like that of those basaltic mountains found in all zones of the earth, which form a long ridge with two terminal cupolas.

([493]) p. 363.—Brooke's Borneo and Celebes, vol. ii. p. 382, 384, and 386.

([494]) p. 364.—Horner, in the Verhandelingen van het Bataviaasch Genootschap van Kunsten en Wetenschappen, Deel xviii. (1839) p. 284; Asie Centr. t. iii. p. 534—537.

([495]) p. 364.—Junghuhn, Java, Bd. ii. S. 809 (Battaländer, Bd. i. S. 39).

([496]) p. 364.—Kosmos, Bd. iv. Anm. 86 to S. 326 (English edit. Note 410).

([497]) p. 365.—Java, Bd. ii. S. 818—828.

([498]) p. 365.—Java, Bd. ii. S. 840—842.

([499]) p. 366.—Java, Bd. ii. S. 853.

([500]) p. 367.—Leop. von Buch, in the Abhandl. der Akad. der Wissensch. zu Berlin, 1818 and 1819. S. 62 ; Lyell, Princ. of Geology (1853), p. 447, where a fine representation of the volcano is given.

([501]) p. 368.—Bory de St.-Vincent, Voy. aux quatre Iles d'Afrique, t. ii. p. 429.

([502]) p. 369.—Valentyn, Beschryving van Oud en Nieuw Oost-Indiën, Deel iii. (1726) p. 70 : Het Eyland St. Paulo. (Compare Lyell, Princ. p. 446.)

([503]) p. 370.—"Nous n'avons pu former," says d'Entrecasteaux, "aucune conjecture sur la cause de l'incendie de l'Ile d'Amsterdam. L'île étoit embrasée dans toute son étendue, et nous avons bien distinctement reconnu l'odeur de bois et de terre brûlés. Nous n'avons rien senti qui pût faire présumer que l'embrasement fût l'effet d'un volcan" (t. i. p. 45). "Cependant," he had said before (p. 43), "l'on a remarqué le long de la côte que nous avons suivie, et d'où la flamme étoit assez éloignée, de petites bouffées de fumée qui sembloient sortir de la terre comme par jets ; on n'a pu néanmoins distinguer la moindre trace de feu tout autour, quoique nous fussions très près de la terre. Ces jets de fumée se montrant par intervalles ont paru à MM. les naturalistes être des indices presqu'assurés de feux souterrains." Should we infer that we have here to do with the ignition of lignites, of which beds covered by basalts and tufa occur so frequently in the volcanic islands of Bourbon, Kerguelen, and Iceland ? The name of Surtarbrand employed in Iceland is taken from Scandinavian mythology, from the Fire-Giant Surtr, who is to set the world on fire. But such earth-fires do not themselves usually occasion flames. As in modern times the names of the islands of Amsterdam and of St. Paul's have unfortunately often been confounded on maps, it may be well, in order that the phænomena observed in the one island may not be erroneously ascribed to the other, to remark that originally (*i. e.* at the end of the seventeenth century), of the two islands lying nearly in the same meridian, it was the southernmost which was named St. Paul's and the northern one Amsterdam. Their discoverer, Vlaming, assigned to the first the latitude of 38° 40′ S., and to the second, 37° 48′ S. These data agree remarkably well in position, as well as in the respective names, with those furnished a century afterwards by D'Entrecasteaux, in the expedition in search of La Pérouse (Voyage, t. i. p. 43—45); namely, for Amsterdam, according to Beautemps-Beaupré, 37° 48′ N. (78° 13′ E.), and for St. Paul, 38° 38′. So close an agreement must be accidental, as the places of observation were, no doubt, not exactly the same. On the other hand, Captain Blackwood in his Admiralty Chart for 1842 gives for St. Paul 38° 44′ S. and 77° 39′ E. In the maps ap-

pended to the original edition of Cook's Voyages, ex. gr. of the first and second expeditions of that circumnavigator of imperishable renown (Voyage to the South Pole and round the World, Lond. 1777, p. 1), as well as of the third and last (Voyage to the Pacific Ocean, published by the Admiralty, Lond. 1784, in 2nd ed. 1785), and even in the account of the three expeditions collectively (A General Chart, exhibiting the Discoveries of Capt. Cook, in this third and two preceding voyages, by Lieut. Henry Roberts), the island of St. Paul is correctly given as the southern one : nevertheless, in the text of D'Entrecasteaux's Voyage (t. i. p. 44), the complaint is made (whether justly appears to me more than doubtful after much examination of editions in the libraries of Paris, Berlin, and Göttingen) that " in the special Chart of Cook's last Expedition Amsterdam Island is placed to the south of St Paul's." Such an inversion of the names, as intended to be given by the original discoverer Willem de Vlaming, is frequently found in maps of the first third of the present century; for example, in the older meritorious Maps of the World of Arrowsmith and Purdy, 1833. This has probably been occasioned rather by : 1. Fault in the Maps of Cox and Mortimer. 2. The circumstance that in the Atlas to Lord Macartney's Voyage to China the smoking volcanic island (of which there is a fine view) is indeed called St. Paul's, and placed in 38° 42′ S., but unfortunately it is subjoined, " commonly called Amsterdam ; " and, what is still worse, in the Narrative of the Voyage, Staunton and Dr. Gillan constantly use the name of Amsterdam for the " island still in a state of inflammation ; " and, after having given the true latitude in p. 219, even add (p. 226) " that St. Paul is lying to the northward of Amsterdam." 3. The same confusion as to the names by Barrow, who in his " Voyage to Cochinchina in the years 1792 and 1793," p. 140—157, also calls the more southern island, " which gives out smoke and flames," Amsterdam. Malte-Brun (Précis de la Géographie Universelle, t. v. 1817, p. 146) justly blames Barrow on this account, but he is wrong in also blaming De Rossel and Beautemps-Beaupré. Both the latter assign to the island of Amsterdam, which is the only one of which they give views, the latitude of 37° 47′; and to the island of St. Paul, as being 50′ more to the south, 38° 38′ (Voy. de D'Entrecasteaux, 1808, t. i. p. 40—46); and, to prove that the drawing in his book represents the true Amsterdam Island of Willem de Vlaming, Beautemps-Beaupré gives in his Atlas a copy of the forest-covered view of Amsterdam from Valentyn. From the circumstance of the celebrated navigator Abel Tasman having, in 1642, with Middelburg called the Island of Tonga-tabu in the Tonga group, in lat. 21½°, Amsterdam (Burney, Chronological History of the Voyages and Discoveries in the South Sea or Pacific Ocean, Pt. III. p. 81 and 437), Tasman has been erroneously cited as the discoverer of

Amsterdam and St. Paul in the Indian Ocean. See Leidenfrost, Histor. Handwörterbuch, Bd. v. S. 310.

([504]) p. 370.—Sir James Ross, Voyage in the Southern and Antarctic Regions, vol. i. p. 46 and 50—56.

([505]) p. 371.—The same, p. 63—82.

([506]) p. 372.—Result of weighings by Professor Rigaud at Oxford, according to Halley's old proposal. See my Asie Centrale, t. i. p. 189.

([507]) p. 373.—D'Urville, Voy. de la Corvette l'Astrolabe, 1826—1829, Atlas Pl.: 1. Polynésie is made to comprise the eastern portion of the Pacific (the Sandwich Islands, Tahiti, and the Tonga Archipelago ; and also New Zealand). 2. Micronésie and Melanésie take the western part of the Pacific Ocean : Micronésie extending from Kauai, the westernmost of the Sandwich Islands, to near Japan and the Philippines, and southwards to the equator, comprising the Marianas or Ladrones, and the Carolinas and Pelew Isles. 3. Mélanesie (from the dark-haired race of men) by its north-west border touching Malaisie, comprises the small groups of Viti or Feejee, the New Hebrides, and Solomon Islands, and the larger islands of New Caledonia, New Britain, New Ireland, and New Guinea. The names of Oceanie and Polynésie, which have been often applied in so contradictory a manner, were introduced by Malte-Brun in 1813, and Lesson in 1828.

([508]) p. 373.—"The epithet *scattered*, as applied to the islands of the ocean (in the arrangement of the groups), conveys a very incorrect idea of their positions. There is a system in their arrangement as regular as in the mountain heights of a continent, and ranges of elevations are indicated, as grand and extensive as any continent presents." (Geology, by J. Dana, or United States' Exploring Expedition under the command of Charles Wilkes, vol. x. (1849) p. 12.) Dana counts in the whole Pacific, omitting mere rock islets, 350 basaltic or trachytic, and 290 coral islands. He divides them into twenty-five groups, of which nineteen have a mean axial direction of N. 50°—60° W., and six have one of N. 20°—30° E. It is an extremely striking circumstance that all this great number of islands (with a few exceptions as the Sandwich Islands and New Zealand) lie between the parallels of 23° 28′ of north and of south latitude, and that there remains so enormous a space without islands between the Sandwich and Nukahiva groups and the American shores of Mexico and Peru. Dana adds a further consideration, which contrasts greatly with the small number of the now active volcanoes : namely, that if we may assume the probability that coral islands, where they are found lying intermediately between islands which are entirely basaltic, rest also on a basaltic foundation, then the number of volcanic

openings below and above the surface of the sea (sub-marine and sub-aerial) would be estimated at upwards of a thousand (p. 17 and 24).

([509]) p. 374.—Compare, in present volume, p. 247 and Note 359.

([510]) p. 375. — Dana, Geology of the U. S. Exploring Expedition, p. 208 and 210.

([511]) p. 375. — Dana, p. 193 and 201. The absence of cones of cinders or ashes is also very remarkable in the Volcanoes of the Eifel which have poured forth streams of lava. That the summit crater of Mouna Loa can send forth eruptions of ashes, is proved by the well-assured accounts which the Missionary Dibble received from the lips of eye-witnesses, and according to which, in the wars of Kamehameha against the insurgents in 1789, an eruption of hot ashes, accompanied by an earthquake, spread a darkness like that of night over the country. (p. 183.) On the volcanic-glass threads (hair of the goddess Pele, who was supposed, before her settlement in Hawaii, to have inhabited the now extinct Volcano Hale-a-kala, the "sun-house," in the Island of Maui), see p. 179 and 199—200.

([512]) p. 375. — Dana, p. 205: "The term *Solfatara* is wholly misapplied. A Solfatara is an area with steaming fissures and escaping sulphur vapours, and without proper lava ejections; while *Kilauea* is a vast crater with extensive lava ejections and no sulphur, except that of the sulphur banks, beyond what necessarily accompanies, as at Vesuvius, violent volcanic action." The framework of Kilauea, the body of the great basin which contains the lava, also by no means consists of strata of ashes or fragmentary rocks, but of horizontal beds of lava superposed like limestone. Dana, p. 193. (Compare Strzelecki, Phys. Descr. of New South Wales, 1845, p. 105—111.)

([513]) p. 376. — This remarkable sinking of the surface-level of the lava has been confirmed by the experience of numerous travellers, from Ellis Stewart and Douglas to the meritorious Count Strzelecki, Wilkes's Expedition, and the attentively observing Missionary Coan. At the great eruption of June 1840, the connection of the rising of the lava in the basin of Kilauea with the sudden inflammation of the much lower situated crater Arare, was most decided. The disappearance of the stream of lava poured forth from Arare, its renewed subterranean course and final reappearance in greater mass, do not allow us to infer its identity with equal certainty, inasmuch as many longitudinal lava-yielding fissures have opened contemporaneously over the whole declivity of the mountain below the level of the floor of the Kilauea basin. As respects the internal constitution of this singular Volcano of Hawaii, it is very noteworthy that, in June 1832, both the craters, that of the summit and that of Kilauea simultaneously, in the one case poured forth, and in the other occasioned, streams of

lava, and were, therefore, simultaneously active. (Compare Dana, p. 184, 188, 193, and 196.)

(514) p. 377. — Wilkes, p. 114, 140, and 157; Dana, p. 221. On account of the perpetual confusion between r and l, Mouna Loa is often written Mouna Roa, and Kilauea Kirauea.

(515) p. 377. — Dana, p. 25 and 138.

(516) p. 378. — Dana, Geology of the U. S. Explor. Exped. p. 138. (Compare Darwin, Structure of Coral Reefs, p. 60.)

(517) p. 379. — Léop. de Buch, Description phys. des Iles Canaries, 1836, p. 393 and 403—405.

(518) p. 380. — Dana, Geol. of the U. S. Expl. Exp. p. 438—446; and on the fresh traces of former volcanic activity in New Holland, p. 453 and 457; and on the numerous basaltic columns in New South Wales and Van Diemen Island, p. 495—510; and P. E. de Strzelecki, Phys. Descr. of New South Wales, p. 112.

(519) p. 381. — Ernest Dieffenbach, Travels in New Zealand, 1843, vol. i. p. 337, 355, and 401. Dieffenbach calls White Island: "a *smoking* solfatara, but still in *volcanic* activity" (p. 358 and 407), and on the map it is stated to be "in continual ignition."

(520) p. 381. — Dana, p. 445—448; Dieffenbach, vol. i. p. 331, 339—341, and 397. On Mount Egmont, see vol. i. p. 131—157.

(521) p. 382. — Darwin, Volcanic Islands, p. 125; Dana, p. 140.

(522) p. 382. — L. de Buch, Descr. des Iles Canaries, p. 365. We find, in the above-named three islands, together with plutonic and sedimentary beds, phonolites and basaltic rocks; but these may have appeared at the first upheaval of the island from the bottom of the sea to above the surface of the waters. No traces either of fiery eruptions within historic times, or of extinct craters, appear to have been found.

(523) p. 383. — Dana, p. 343—350.

(524) p. 383. — Dana, p. 312, 318, 320, 323.

(525) p. 383. — L. von Buch, p. 383; Darwin, Volcanic Islands, p. 25; Darwin, Coral Reefs, p. 138; Dana, p. 286—305, and 364.

(526) p. 385. — Dana, p. 137.

(527) p. 585. — Darwin, Volc. Isl. p. 104, 110—112, and 114. If Darwin says so decidedly that trachytes are entirely wanting in the Galapagos, it is because he restricts the term trachyte to common felspar, *i. e.* orthoclase, or to orthoclase and sanidine (glassy felspar). The curious inbaked or embedded pieces in the lava of the small and entirely basaltic crater of James Island contain no quartz, although they appear to rest on a plutonic rock. (Compare, in

present volume, pp. 300 and 331.) Several of the volcanic cones in the Galapagos Islands have, at the mouth, quite as I have seen at Cotopaxi, a narrow *cylindrical* parapet. "In some parts, the ridge is surmounted by a wall or parapet perpendicular on both sides." Darwin, Volc. Isl. p. 83.

([528]) p. 386. — L. von Buch, p. 376.

([529]) p. 386. — Bunsen, in Leonhard's Jahrb. für Mineralogie, 1851, S. 856; and in Poggend. Annalen der Physik, Bd. lxxxiii. S. 223.

([530]) p. 387. — Kosmos, Bd. iv. S. 311—313, and Anm. 70 (present volume p. 268—269, and Note 394).

([531]) p. 387. — See Pieschel, Ueber die Vulkane von Mexico, in the Zeitschrift für Allg. Erdkunde, Bd. vi. 1856, S. 86 and 489—532. The statement (S. 86) that "no mortal had ever climbed the steep point of the Pico del Fraile" is strangely erroneous, and is refuted by Dr. Gumprecht in the same volume (S. 489). The tower-like summit which is only ten feet broad is, indeed, of difficult attainment; but I gained it, and observed the barometer there on the 29th of September 1803, and published the observations so long ago as 1807. Moreover, I struck off, and brought home, pieces from the mass of trachyte where it had been pierced by lightning, glazed on the inside like lightning tubes. Gilbert, in 1819, in Bd. lxi. of his Annalen der Physik, S. 261, gave a memoir on these pieces which had been laid by me before meetings both of the Berlin and Paris Academies. (Compare also Annales de Chimie et de Physique, t. xix. 1822, p. 298.) Where the lightning had pierced cylindrical tubes three inches long, in such a manner that the upper and lower openings could be distinguished apart, the rock surrounding these openings was also vitrified. I have also, in my collection, pieces where, as at the Lesser Ararat and Mont Blanc, the whole surface has been vitrified without tubular perforation. Herr Pieschel, in October 1852, was the first who ascended the Volcano of Colima with its double summit, and arrived at the crater from which he then saw hot vapours of sulphuretted hydrogen issue in clouds. Sonneschmid, who, in February 1796, attempted the ascent of Colima, but without success, reported accounts of a great eruption of ashes in 1770. In March 1795, glowing scoriæ were ejected, presenting at night the appearance of a pillar of fire. "To the north-west of the Volcano of Colima, a volcanic branch fissure runs along the shore of the Pacific. Extinct craters and ancient lava-streams can be recognised in what are called the Volcanoes of Ahuacatlan (on the route from Guadalaxara to San Blas) and of Tepic." (Pieschel, in the volume above referred to, S. 529.)

([532]) p. 388. — Kosmos, Bd. iv. S. 392—397 (present volume, p. 348 to 355).

([533]) p. 389. — The name of "Grand Océan" for the basin of the Pacific,

introduced by my friend the learned geographer Contre-Amiral de Fleurieu, the author of the Introduction historique au Voyage de Marchand, has the fault of giving to a part the name of the whole, and tends, therefore, to cause confusion.

([534]) p. 391. — On the axis of the greatest heights or culminating points, and of the volcanoes in the tropical zone of Mexico, see Kosmos, Bd. iv. S. 312 and 343 (in the present volume, p. 268 and 299). Compare also Essai pol. sur la Nouv. Esp. t. i. p. 257—268, t. ii. p. 173; and Ansichten der Natur, Bd. i. S. 344—350.

([535]) p. 392. — By Juan de Oñate, 1594. Memoir of a Tour to Northern Mexico in 1846 and 1847, by Dr. Wislizenus. On the influence which the peculiar form of the ground (the great magnitude of the table-land) may be expected to exert on internal traffic and on the intercourse of the tropical zone with the north, whenever social order, civil liberty, and industry shall be enjoyed, compare Essai pol. t. iv. p. 38; and Dana, p. 612.

([536]) p. 392. — In this tabular view of elevations between Mexico and Santa Fé, as in the similar, but less complete, one given in my Ansichten der Natur, Bd. i. S. 349, the initials B., W., and H. signify the names of the observers: W. being Dr. Wislizenus, author of a very instructive and scientific work, Memoir of a Tour to Northern Mexico connected with Colonel Doniphan's Expedition in 1846 and 1847 (Washington, 1848); B., Oberbergrath Burkart; and H., myself. At the time when I was engaged in astronomical determinations of latitude and longitude in the tropical parts of New Spain (from March 1803 to February 1804), and when, from all the materials that I could discover and discuss, I ventured to prepare a general map of the entire country, of which map my honoured friend, Thomas Jefferson, then President of the United States, had a copy made which has since been often much misemployed, there were as yet no determinations of latitude in the interior of the country, on the route to Santa Fé, north of Durango (24° 25′ N.). According to two manuscript accounts of travels found by me in the archives of Mexico, of the engineers Rivera, Lafora, and Mascaró, in 1724 and 1765, containing compass bearings and estimated partial distances, careful calculation gave for the important station of Santa Fé 36° 12′ N., and 105° 51′ W. (from Don Pedro de Rivera). (See my Atlas géogr. et phys. du Mexique, Tab. VI.; and Essai pol. t. i. p. 75, 82.) In the analysis of my map, I have carefully stated this result to be a very uncertain one, inasmuch as, in estimations of distance and compass bearings, without correction for the magnetic declination, and with the want of objects in treeless plains without human habitations, on an extent of 1200 geogr. miles, it cannot be safely assumed that all errors compensate each other (t. i. p. 127—131). It happens accidentally that

the above result, compared with the latest astronomical determinations, is much more erroneous in latitude than in longitude, differing in latitude thirty-one minutes, and in longitude scarcely as much as twenty-three minutes of arc. I also succeeded in determining, with approximate correctness, by means of combinations, the position of the Lake of Timpanogos, now commonly called the Great Salt Lake; the river which runs into the smaller Utah Lake (a fresh-water lake) now alone retains the name, being called the Timpanogos River. In the language of the neighbouring Utah Indians, the river is called Og-wahbe, and by abbreviation Ogo only; timpan is rock, therefore Timpan-ogo is rocky river. (Fremont, Expl. Exped. 1845, p. 273.) Buschmann explains the word timpa as arising out of the Mexican tetl, rock, having discovered in "pa" a native North-Mexican substantive ending; he assigns to ogo the general signification of water; see his work entitled "Die Spuren der aztekischen Sprache im nördlichen Mexico, S. 354—356 and 351. The "Great Salt Lake City" of the Mormons is in 40° 46′ N., 112° 04′ W. Compare Expedition to the Valley of the Great Salt Lake of Utah, by Captain Howard Stansbury, 1852, p. 300; and Humboldt, Ansichten der Natur, Bd. i. S. 346. My map gives "Montagnes de Sel Gemme" somewhat to the east of the Laguna de Timpanogos, 40° 7′ N., 111° 47′ W.; therefore my first conjecture differed in latitude thirty-nine, and in longitude seventeen minutes. The latest determinations of the position of Santa Fé, the capital of New Mexico, with which I am acquainted, are: — *a.* according to many star altitudes determined by Lieut. Emory (1846), 35° 44′ 6″; *b.* according to Gregg and Dr. Wislizenus (1848), perhaps at a different spot, 35° 41′ 6″. Emory's longitude is $7^h\ 4^m\ 18^s$ of time west of Greenwich; Wislizenus's is 28′ of arc less westerly. (New Mexico and California, by Emory, Docum. No. 41, p. 36; Wisl. p. 29.) The error of most maps of the country about Santa Fé is to make places too northerly. The elevation of the town of Santa Fé above the sea is, according to Emory, 6422, and according to Wislizenus, fully 6611 Paris feet; mean, 6516 (or 6944 English) feet; therefore equal to the height of the passes of the Splugen and the St. Gothard in the Swiss Alps.

([537]) p. 392. — The latitude of Albuquerque is taken from the good special map entitled Map of the Territory of New Mexico, by Kern, 1851. The elevation is, according to Emory (p. 166), 4750 feet; but according to Wislizenus (p. 122), 4859 feet.

([538]) p. 392. — On the latitude of Paso del Norte, compare Wislizenus, p. 125, Met. Tables VIII. to XII. Aug. 1846.

([539]) p. 394. — Compare Fremont, Report of the Exploring Exped. in 1842, p. 60; Dana, Geology of the U. S. Expl. Exp. p. 611—613; and for South

America, Alcide d'Orbigny, Voy. dans l'Amérique mérid. Atlas, Pl. VIII. de Géologie spéciale, Fig. 1.

([540]) p. 394. — Respecting this bifurcation, and the correct names of the eastern and western chains, compare the great Special Map of the Territory of New Mexico, by Parke and Kern, 1851; Edwin Johnson's Map of Railroads, 1854; John Bartlett's Map of the Boundary Commission, 1854; Explorations and Surveys from the Mississipi to the Pacific in 1853 and 1854, vol. i. p. 15; and, above all, the comprehensive and excellent work of Jules Marcou, geologist of the Southern Pacific R. R. Survey under the command of Lieut. Whipple, Résumé explicatif d'une Carte géologique des États Unis et d'un Profil géologique allant de la Vallée du Mississipi aux Côtes de l'Océan Pacifique, p. 113—116; also in the Bulletin de la Société Géologique de France, 2e série, t. xii. p. 813. In the longitudinal valley enclosed by the Sierra Madre and Rocky Mountains, in 35°—38°½ N., the single groups, of which the western chain of the Sierra Madre and eastern chain of the Rocky Mountains (Sierra de Sandia) consist, bear special names. To the first-named chain belong (proceeding from south to north) the Sierra de las Grullas, the Sierra de los Mimbres (Wislizenus, p. 22 and 54), Mount Taylor (35° 15′ N.), Sierra de Jemez, and Sierra de San Juan; in the easternmost chain of the Rocky Mountains may be distinguished the Moro Peaks, the Sierra de la Sangre de Christo with the eastern Spanish Peaks (lat. 37° 32′), and the White Mountains which turn north-westward and enclose the longitudinal valley of Taos and Santa Fé. Professor Julius Pröbel, whose examination of the volcanoes of Central America I have already spoken of, has, with much sagacity, developed the indefiniteness of the geographical name Sierra Madre in the older maps; but, at the same time, in a treatise entitled Remarks contributing to the physical Geography of the North-American Continent (Ninth Annual Report of the Smithsonian Institution, 1855, p. 272—281) he has put forward a view to which, after discussing the many now existing materials, I cannot accede: it is to the effect that the Rocky Mountains are by no means to be regarded as a continuation of the Mexican highland in the tropical portion of Anahuac. Uninterrupted mountain-chains, as in the Apennines, the Swiss Jura, the Pyrenees, and a great part of our Alps, are not, indeed, to be found running from south-south-east to north-north-west between the nineteenth and the forty-fourth parallels of latitude, from Popocatepetl in Anahuac to north of Fremont's Peak in the Rocky Mountains; but the enormous general elevation of the surface, which increases more and more in breadth towards the north and north-west, is continuous from tropical Mexico to Oregon; and on this swelling high plain, which is the primary and principal geological phænomenon, single groups of mountains rise over fissures which have taken

place at more recent and very different periods from each other, and often in very different directions. These groups of mountains, thus rising from a high platform, are so connected in the Rocky Mountains as to form a rampart extending through eight degrees of latitude; and being rendered conspicuous to a great distance by conical summits, chiefly trachytic, twelve and thirteen thousand feet high, they produce on the traveller the more impression (it appears to me), because to the eye they have, illusively, the effect of rising direct from a lowland plain. Although in the Cordilleras of South America, of which I know a considerable portion from having myself explored them, it has been customary, from the time of La Condamine, to speak of a double and triple range (the Spanish expression "Cordilleras de los Andes" refers to such arrangement and division); yet it is not to be forgotten that here also the directions of particular groups, whether as long ridges or as a series of domes, are by no means generally parallel to each other or to the direction of the entire chain.

([541]) p. 395. — Fremont, Explor. Exped. p. 281—288: Pike's Peak, lat. 38° 50′, drawn in p. 114; Long's Peak, in 40° 15′; the ascent of Fremont's Peak, 13,570 feet high, is described in p. 70. The Wind River Mountains take their name from the sources of a tributary to the Big Horn River, whose waters unite with those of the Yellow Stone River which falls into the Upper Missouri in 47° 58′ N., 103° 05′ W. See the drawings of mountains having much mica-slate and granite, in pp. 66 and 70. A change of direction takes place in the chain of the Rocky Mountains between the parallels of Pike's Peak and Lewis' and Clark's Pass, when it turns more to the west. This circumstance is recalled for the sake of comparison with the chain of the Ural which, according to the arduous examinations of my friend and travelling companion Colonel Ernst Hofmann, turns eastward near its northern extremity. Its length is fully 1020 geographical miles from the Truchmenian mountain Airuck-Tagh in $48^\circ\frac{3}{4}$ N. to the Sablja Mountains in 65° N.; in the course of these seventeen degrees of latitude it deviates but little from the meridian of 59° E. of Greenwich, but in 65° it bends, as aforesaid, to the eastward, so as to reach the meridian of 66° E. in the parallel of $67^\circ\frac{1}{2}$ N. Compare Ernst Hofmann, Der nördliche Ural und das Küsten-Gebirge Pac-Choi, 1856, S. 191 and 297—305, with Humboldt, Asie Centrale (1843), t. i. p. 447.

([542]) p. 396. — Kosmos, Bd. iv. S. 321 (present volume, p. 277).

([543]) p. 397. — The Raton Pass, according to an itinerary map of 1855 belonging to the General Report of the Secretary of State, Jefferson Davis, is 7180 feet above the sea. Compare also Marcou, Résumé explicatif d'une Carte géol. 1855, p. 113.

([544]) p. 397. — We distinguish, proceeding from east to west, the ridges of

Zuñi, where the Paso de Zuñi is still 7944 feet high; Zuñi Viejo, the old ruined Pueblo drawn by Möllhausen in Whipple's Expedition; and the present inhabited Pueblo de Zuñi. Forty geographical miles north of the last-named place, there is still a very small isolated volcanic district near Fort Defiance. Between the village of Zuñi and the slope to the little Colorado River (Colorado Chiquito), there lies uncovered the "petrified forest," of which an excellent description and drawings have been given by Möllhausen in 1853 in a memoir sent to the Geographical Society of Berlin. Among the silicified coniferæ, fossil tree-ferns are also interspersed, according to Marcou (Résumé explic. d'une Carte géol. p. 59).

([545]) p. 398. — All, according to the profiles by Marcou and from the above-cited itinerary map of 1855.

([546]) p. 398. — The French names introduced by Canadian fur-hunters are in general use in the country and in English maps. The relative positions of the extinct volcanoes are, according to the latest determinations, as follows: — Fremont's Peak, 43° 5′ N., 110° 8′ W.; Trois Tétons, 43° 38′ N., 110° 48′ W.; Three Buttes, 43° 20′ N., 112° 40′ W.; Fort Hall, 43° 0′ N., 112° 23′ W.

([547]) p. 398. — Lieut. Mullan, On the volcanic Formation, in the Reports of Explor. and Surveys, vol. i. (1855) p. 330 and 348; see also Lambert's and Tinkham's account of the Three Buttes, in the same, p. 167 and 226—230; and Jules Marcou, p. 115.

([548]) p. 400. — Dana, p. 616—621: Blue Mountains, p. 649—651; Sacramento Butt, p. 630—643; Shasty Mountains, p. 614; Cascade Range. On the Monte Diablo Range which has broken through volcanic rock, see also John Trask, On the Geology of the Coast Mountains and the Sierra Nevada, 1854, p. 13—18.

([549]) p. 400. — Dana (p. 615 and 640) estimated the volcano St. Helen's at 16,000 feet, and Mount Hood, therefore, at less than that height; according to others, Mount Hood would have the great elevation of 18,316 feet, 2526 feet higher than Mont Blanc, and 4746 feet higher than Fremont's Peak in the Rocky Mountains. Thus, according to the latter statement (Landgrebe, Naturgeschichte der Vulkane, Bd. i. S. 497), Mount Hood would, on the one hand, be only 571 feet lower than Cotopaxi; while, according to that of Dana, on the other hand, it would only be 2550 feet above the highest summit in the Rocky Mountains. I always think it desirable to call attention to such "variantes lectiones."

([550]) p. 400. — Dana, Geol. of the U.S. Explor. Exp. p. 640 and 643—645.

([551]) p. 401. — Older various statements of this elevation are: 10,178 feet according to Wilkes, and 13,535 feet according to Simpson.

(552) p. 402. — Karsten's Archiv für Mineralogie, Bd. i. 1829, S. 243.

(553) p. 402. — Humboldt, Essai politique sur la Nouv. Esp. t. i. p. 266; t. ii. p. 310.

(554) p. 402. — According to a manuscript which I was enabled to avail myself of in 1803 in the archives of Mexico, the whole coast from Nootka to what was subsequently called Cook's Inlet was visited in 1774 by the expedition of Juan Perez and Estevan José Martinez. (Essai pol. sur la Nouv. Esp. t. ii. 296—298).

(555) p. 406. — In the Antilles, volcanic activity is confined to the lesser islands; three or four still active volcanoes having broken forth on a rather curved fissure, approaching to a north and south direction, and tolerably parallel to the volcanic fissure of Central America. I have elsewhere — on the occasion of the considerations suggested by the simultaneity of the earthquakes in the valleys of the Ohio, Mississippi, and Arkansas Rivers with those in the valley of the Orinoco and on the coast of Venezuela — described the Caribbean Sea as forming, according to geognostical views, in connection with the Gulf of Mexico and the great plain of Louisiana between the Alleghanies and the Rocky Mountains, one great ancient basin. (Voyage aux Régions équinoxiales, t. ii. p. 5 and 19.) This basin is traversed, through its centre, between 18° and 22° N. lat., by a plutonic mountain range from Cape Catoche on the peninsula of Yucatan to the islands of Tortola and Virgen gorda. Cuba, Haiti, and Porto Rico form a west and east range running parallel to the granite and gneiss chain of Caracas. On the other hand, the mostly volcanic small Antilles connect the above alluded to plutonic chain of the greater Antilles and that of the coast of Venezuela with each other, and close the southern portion of the basin on its eastern side. The still active volcanoes of the lesser Antilles are between the parallels of 13° and 16½°. Proceeding from south to north, they are as follows: —

The volcano in the island of St. Vincent, estimated sometimes at 3200, sometimes at 5050 feet. After its eruption in 1718, it was at rest until a fresh one occurred on the 27th of April 1812, sending forth an enormous quantity of lava. The first movements, near the crater, began in May 1811, three months after the island of Sabrina had risen from the sea in the Azores. In the mountain valley of Caracas, 3496 feet above the sea, they began to be faintly felt in December of the same year. The complete destruction of the large town of Caracas took place on the 26th of March of the following year, 1812. As the earthquake which destroyed Cumana on the 14th Dec. 1796 was with reason ascribed to the eruption of the volcano of Guadeloupe at the end of September 1796, so the destruction of Caracas appears to have been an effect of the reaction

of a more southerly West-Indian volcano, that of the island of St. Vincent. The dreadful subterranean noise resembling thunder or the sound of a heavy cannonade, caused by a violent eruption of the last-named volcano on the 30th of April 1812, was heard in the wide grassy plains (the Llanos) of Calabozo and on the banks of the Rio Apure, 192 geographical miles to the west of its confluence with the Orinoco. (Humboldt, Voy. t. ii. p. 14.) The volcano of St. Vincent had not sent forth any lava between 1718 and 1812; on the 30th of April, a stream of lava flowed from the summit-crater, and in the course of four hours reached the sea-shore. It is a very curious fact, and one that was confirmed to me by very intelligent persons engaged in coasting navigation, that the noise was heard with much greater strength far out at sea than in the immediate vicinity of the island.

The volcano of the island of Santa Lucia, which is commonly termed a Solfatara, is only between twelve and eighteen hundred feet high. There are in the crater several small basins which are periodically filled with boiling water. In 1766, an eruption of scoriæ and ashes is said to have been observed, which is, indeed, an unusual phænomenon for a Solfatara; for although it appears, from very well carried out investigations by James Forbes and Poulett Scrope, that there can scarcely be a doubt as to the fact of an eruption of the Solfatara of Pozzuoli in 1198, yet we might be inclined to regard this occurrence as a lateral effect of the neighbouring principal volcano, Vesuvius. (See Forbes, in the Edinb. Journal of Science, vol. i. p. 128; and Poulett Scrope, in the Transact. of the Geol. Soc. 2nd series, vol. ii. p. 346.) Lancerote, Hawaii, and the Sunda isles present to us analogous examples of eruptions, situated at extreme distances from the summit-craters which are the proper seats of the volcanic activity. In the great eruptions of Vesuvius in 1794, 1822, 1850, and 1855, the Solfatara of Pozzuoli has remained undisturbed (Julius Schmidt, Ueber die Eruption des Vesuvs im Mai 1855, S. 156); although Strabo (liv. v. p. 245), long before the breaking out of Vesuvius, speaks, although vaguely, of fire also in the region of Dicæarchia (Dicæarchia received in Hannibal's time, from the Romans who colonised there, the name of Puteoli. Strabo adds, "Some think that, on account of the bad smell of the water, the whole district, as far as Baiæ and Kymæa, is called so, because it is full of sulphur, fire, and warm water. Some think that for this reason also Kymæa, Cumanus Ager, was also called Phlegra;" and afterwards Strabo speaks of fire and water being poured forth, *προχοὰς τοῦ πυρὸς καὶ τοῦ ὕδατος*).

The modern volcanic activity of the island of Martinique in the Montagne Pelet (4706 feet high according to Dupuget), Vauclin, and the Pitons du Carbet is still more doubtful. The great outbursts of vapour of January 22, 1792,

described by Chisholm, and the showers of ashes of August 5, 1851, deserve to be more closely inquired into.

The Soufrière de la Guadeloupe, according to the older measurements of Amic and Le Boucher 5435 and 5109 feet high, but according to the most recent and very exact ones of Charles Sainte-Claire Deville only 4867 feet high, showed itself to be a pumice-ejecting volcano on the 28th of September 1797, seventy-eight days therefore before the great earthquake and the destruction of the town of Cumana. (Rapport fait au Général Victor Hugues, par Amic et Hapel, sur le Volcan de la Basse Terre, dans la nuit du 7 au 8 vendémiaire, an 6, p. 46; Humboldt, Voyage, t. i. p. 316.) The lower part of the mountain is of dioritic rock; the volcanic cone whose summit is opened is trachyte containing labradorite. The mountain, which, on account of its ordinary condition, is called the Soufrière, never appears to have sent forth lava in streams, either from the summit-crater, or from lateral fissures; but the ashes of the eruptions of Sept. 1797, Dec. 1836, and Feb. 1837, examined by the excellent and lamented Dufrénoy with the accuracy which characterised him, were found to consist of finely triturated fragments of lava, in which felspathic minerals (labradorite, rhyakolite, and sanidine), together with pyroxene, were recognised. (See Lherminier, Daver, Elie de Beaumont, and Dufrénoy, in the Comptes rendus de l'Acad. des Sc. t. iv. 1837, p. 294, 651, and 743—749.) Also Deville recognised in the trachytes of the Soufrière small fragments of quartz, together with labradorite crystals (Comptes rendus, t. xxxii. p. 675); as Gustav Rose did hexagonal dodecahedrons of quartz in the trachytes of the Volcano of Arequipa. (Meyen, Reise um die Erde, Bd. ii. S. 23.)

The phænomena here described, of the ejection, during a period of short continuance, of very various mineralogical substances from the fissured apertures of a soufrière, remind us forcibly that what we commonly call solfataras, soufrières, or fumaroles, are, strictly speaking, only the indications of certain states of volcanic activity. Volcanoes which once poured forth lavas, or, failing these, ejected unconnected scoriæ of considerable bulk, or lastly, the same scoriæ reduced by friction to a state of powder, in a later stage of diminished activity arrive at a condition in which they furnish only sulphur sublimates, sulphurous acid, and aqueous vapour or steam. If we were to call them in this state semi-volcanoes, we might be likely thereby to give occasion to the idea of their being a peculiar class of volcanoes. Bunsen — to whom, together with Boussingault, Senarmont, Charles Deville, and Daubrée, science is indebted for such valuable advances obtained by the ingenious and happy application of chemistry to geology, and more especially to volcanic processes — has shown the manner in which, when in sublimations of sulphur, which almost always accompany volcanic eruptions,

the sulphurous vapour encounters glowing pyroxenic rocks, sulphurous acid originates in the partial decomposition of the oxide of iron which those rocks contain. If thereafter the volcanic activity sinks to lower temperatures, the chemical activity enters upon a new phase. The combinations of sulphur with iron, and perhaps with the metallic bases of the earths and alkalies, begin to act on the aqueous vapour or steam, and, as a result of reciprocal action, there arise sulphuretted hydrogen, and the products of its decomposition, viz. free hydrogen and vapours of sulphur. Sulphur fumaroles survive great volcanic eruptions for centuries. The muriatic acid fumaroles belong to a different and a later period: it is but rarely that they assume the character of permanent phænomena. The origination of muriatic acid in crater gases may be inferred to be from the muriate of soda, which so frequently appears as a product of sublimation in volcanoes (and in Vesuvius in particular), being decomposed by silicates, at high temperatures and under the concurrent action of aqueous vapour, into muriatic acid and soda, which latter combines with the silicates which are present. Muriatic acid fumaroles, which in Italian volcanoes occur not unfrequently on a very large scale, and which are then usually accompanied by great sublimations of common salt (muriate of soda), appear to be only very inconsiderable in Iceland. As the final links in the chronological series of all these phænomena we find lastly the emanations of carbonic acid gas only. The hydrogen in volcanic gases has hitherto been almost entirely overlooked. It is present in the vapour spring of the great solfataras of Krisuvik and Reykjalidh, in Iceland, and at both those places is combined with sulphuretted hydrogen. As the latter and sulphurous acid, on coming into contact, mutually decompose each other, setting free the sulphur, they never can both present themselves at once. It is not rare, however, to find them in one and the same fumarole field very near each other. If in the Icelandic solfataras, which have just been named, sulphuretted hydrogen gas could so little be recognised, on the other hand, it was entirely wanting in the solfatara state of the crater of Hecla only a short time after the eruption of 1845, therefore in the first phase of volcanic after-action. Neither by smell nor by reagents could the slightest trace of sulphuretted hydrogen be discovered, while the abundant sublimation of sulphur made the presence of sulphurous acid unmistakably recognisable by the smell to a considerable distance. It is true that on bringing a lighted cigar over the fumaroles those thick clouds of smoke showed themselves, which Melloni and Piria (Comptes Rendus, t. xi. 1840, p. 352; and Poggendorff's Annalen, Ergänzungsband, 1842, S. 511) have pointed out as an indication of the smallest traces of sulphuretted hydrogen. As however it is easy to satisfy one's-self by experiment, that sulphur by itself, when sublimated with aqueous vapours, also produces the same phænomenon, it remains

doubtful whether even a trace of sulphuretted hydrogen accompanied the emanations of Hecla in 1845 and of Vesusius in 1843. (Compare the excellent and, in geological respects, highly important Memoir of Robert Bunsen, on the processes of volcanic rock formation in Iceland, in Poggend Ann. Bd. 83, 1851, S. 241, 244, 246, 248, 250, 254, and 256 : enlarging and correcting the Memoirs of 1847, in Wöhler's and Liebig's Annalen der Chemie und Pharmacie, Bd. 62, S. 19.) That the emanations of the solfataras of Pozzuoli were not of sulphuretted hydrogen, and did not deposit sulphur on contact with the atmosphere, as had been asserted by Breislak, in his memoir, entitled, Essai Minéralogique sur la Soufrière de Pozzuoli, 1792, p. 128—130, had been already remarked by Gay-Lussac, when we visited the Phlegraean fields together at the time of the great lava eruption of 1805. The clear-sighted Arcangelo Scacchi (Memorie Geologiche sulla Campania, 1849, p. 49—121) very decidedly denies the existence of the sulphuretted hydrogen, because Piria's methods of testing appear to him only to prove the presence of aqueous vapour : " Son di aviso che lo solfo emane mescolato a i vapori acquei senza essere in chimica combinazione con altre sostanze." An actual analysis (which I had long wished for and expected) of the gases emitted by the solfatara of Pozzuoli has been only very recently furnished by Charles Sainte-Claire Deville and Leblanc, and has fully confirmed the absence of sulphuretted hydrogen. (Comptes Rendus de l'Acad. des Sc. t. xliii. 1856, p. 746.) On the other hand, Sartorius von Waltershausen (Physisch-geographische Skizze von Island, 1847, S. 120) remarked at the eruption cones of Etna, in 1811, the strong smell of sulphuretted hydrogen, where, in other years, only sulphurous acid had been perceived. Ch. Deville found a small portion of sulphuretted hydrogen, not at Girgenti and in the Macalube, but on the eastern slope of Etna, in the spring of Santa Venerina. It is a striking circumstance, that, in the important series of chemical analyses which Boussingault made on gas-emitting volcanoes in the chain of the Andes (from Puracé and Tolima to the high plains of Los Pastos and Quito), both muriatic acid and hydrogène sulfureux are wanting.

(556) p. 406. — Older works give as the number of still burning volcanoes:— Werner, 193; Cæsar von Leonhard, 187; Arago (Astronomie populaire, t. iii. p. 170), 175; all less than my number, the differences in defect varying between $\frac{1}{8}$ and $\frac{1}{4{,}5}$, and being attributable partly to diversity in the principles by which the continuance of ignition is judged of, and partly by deficiency in the data collected. Since, as I have already remarked above, and as historic experience teaches us, volcanoes, which had been believed to be extinct, have again manifested their activity after long periods of repose, the numerical result propounded by me is rather to be regarded as too low than too high. Leopold

von Buch, in the Appendix to his masterly description of the Canaries, and Landgrebe, in his Geography of Volcanoes, have not hazarded any general numerical estimate.

([557]) p. 407. — This description is quite opposed to the often repeated representation of "Vesuvius according to Strabo," given in Poggendorff's Annalen der Physik, Bd. xxxvii. S. 190, Tafel I. A very late writer, Dio Cassius, under Septimius Severus, was the first to discuss, not the origination of several summits, as has often been asserted, but the first who tried to show how in course of time the form of the summit has altered. He recalls (quite in confirmation of what had been said by Strabo) that formerly the mountain had an everywhere flat summit. His words (lib. lxvi. cap. 21, ed. Sturz, vol. iv. 1824, p. 240) are to this effect: — "For Vesuvius is situated on the sea near Naples, and has abundant sources of fire. The whole mountain was formerly of equal height, and the fire rose out of its middle; for in that part only it is burning, its whole outside being free from fire. Since then the exterior is always without fire, while the interior is parched with heat and turned into ashes; the pointed parts around have hitherto retained their ancient height, while the whole fiery inside, consumed by time, has sunk down and become hollow, so that, to compare great things with small, the mountain resembles an amphitheatre." (Compare Sturz, vol. vi. annot. ii. p. 568.) This is a sufficiently clear description of those parts of the mountain which, since the year 79, have become the crater-margins. The interpretation which refers this passage to the Atrio del Cavallo appears to me incorrect. According to the excellent hypsometric investigation made in 1855 by the active and distinguished Olmütz astronomer, Julius Schmidt, Punta Nasone of the Somma is 3772 feet high; the Atrio del Cavallo at the foot of Punta Nasone, 2666 feet; and Punta, or Rocca, del Palo (the highest northern crater-margin of Vesuvius), 3990 feet. My barometric measurements in 1822 (Ansichten der Natur, Bd. ii. S. 290—292) gave for the same three points 3746, 2577, and 4022 feet (the differences are 26, 89½, and 32 feet). The floor of the Atrio del Cavallo has undergone great alterations of level since the eruption in February 1850, according to Julius Schmidt (Eruption des Vesuvs im Mai 1855, S. 95).

([558]) p. 408. — Velleius Paterculus, who died under Tiberius, does, indeed (ii. 30), name Vesuvius as the mountain which Spartacus occupied with his gladiators; whereas Plutarch, in the biography of Crassus, cap. ii., speaks only of a locality amidst rocks having a single narrow entrance. The servile war of Spartacus was in the year of Rome 681, therefore 152 years before Pliny's eruption of Vesuvius, on the 24th of August 79 A.D. That Florus — a writer living under Trajan, and who, therefore, being cognizant of the eruption just

named, was aware of the hidden contents of the recesses of the mountain — should have spoken of it as "cavus," can, as has been already remarked by others, prove nothing as to its earlier condition. (Florus, lib. i. cap. 16: Vesuvius mons, Ætnæi ignis imitator; lib. iii. cap. 20: fauces cavi montis.)

([559]) p. 409. — It is in any case certain that Vitruvius wrote earlier than the elder Pliny; not only because he is cited three times in the list of Pliny's authorities, wrongly assailed by the English translator Newton (lib. xvi., xxxv., and xxxvi.), but because a passage in book xxxv. cap. 14, § 170—172, has been distinctly proved, by Sillig (vol. v. 1851, p. 277) and Brunn (Diss. de Auctorum Indicibus Plinianis, Bonnæ, 1856, p. 55—60), to have been extracted by Pliny himself from our Vitruvius. Compare also Sillig's edition of Pliny, vol. v. p. 272. Hirt, in his memoir on the Pantheon, places the writing of Vitruvius's architecture between the years 16 and 14 B.C.

([560]) p. 409. — Poggendorff's Annalen, Bd. xxxvii. S. 175—180.

([561]) p. 409. — Carmine Lippi: "Fu il fuoco o l'acqua che sotterrò Pompei ed Ercolano?" 1816, p. 10.

([562]) p. 409. — Scacchi, Osservazioni critiche sulla Maniera come fu sepellita l'antica Pompei, 1843, p. 8—10.

([563]) p. 411. — Sir James Ross, Voyage to the Antarctic Regions, vol. i. p. 217, 220, and 364.

([564]) p. 412. — Gay-Lussac, Réflexions sur les Volcans, in the Annales de Chimie et de Physique, t. xxii. 1823, p. 427; Kosmos, Bd. iv. S. 218, English edition, p. 170; Arago, Œuvres complètes, t. iii. p. 47.

([565]) p. 413. — Reduced to Timana, the Volcan de la Fragua is in about 1° 48′ N., and 75° 30′ W. Compare, in the Atlas to my Travels, the Carte hypsométrique des Nœuds de Montagne dans les Cordillères, 1831, Pl. V., and also Pl. XXII. and XXIV. This mountain, situated so far to the east, and so much by itself, deserves to be visited by a geologist who shall also be able to determine longitudes and latitudes astronomically.

([566]) p. 414. — In the three groups which, according to the old geographical nomenclature, belong to Auvergne, the Vivarais, and the Velay, the distances stated in the text are taken, in each case, from the northernmost part of the group to the Mediterranean, between the Golfe d'Aigues Mortes and Cette. In the first group, that of the Puy de Dôme, the northernmost point referred to is a crater which has broken forth in the granite near Manzat, and is called Le Gour de Tazena. (Rozet, in the Mém. de la Soc. Géol. de France, t. i. 1844, p. 119.) Still more to the south than the group of the Cantal, and therefore nearest to the sea, at a distance from it of about seventy miles, is the small

volcanic district of La Guiolle, near the Monts d'Aubrac, north-west of Chirac. Compare the Carte géologique de France, 1841.

([567]) p. 414. — Humboldt, Asie Centrale, t. ii. p. 7—61, 216, and 335—364; Kosmos, Bd. i. S. 254 (English edition, p. 232, 233). I find the Alpine lake of Issikul, on the northern slope of the Thian-schan, which has only recently been reached by Russian travellers, already marked on the celebrated Catalonian Map of 1374, which is preserved as a gem among the manuscripts of the Paris library. Strahlenberg, in his work entitled "Der nördliche und östliche Theil von Europa und Asien" (Stockholm, 1730, S. 327), has the merit of having been the first to represent the Thian-schan as an independent chain, but without recognising in it volcanic activity. He gave it the very indefinite name of Mousart, which, inasmuch as the Bolor chain had the general un-individualising name of Mustag, signifying snow, gave occasion for another century to erroneous representations and a bad and contradictory set of names for the mountain ranges north of the Himalaya, causing the chains which follow parallels of latitude, and those which follow the direction of the meridian, to be confounded with each other. Mousart is a corruption of the Tartar word Muztag, which has the same meaning as our Snow mountains, Sierra Nevada of the Spaniards; Himalaya in the Institutes of Menu, habitation (álaya) of snow (hîma); and the Sine-schan of the Chinese. Eleven hundred years before Strahlenberg, under the dynasty of the Sui, in the time of the Frankish king Dagobert, the Chinese possessed maps, constructed by the order of their government, of the countries from the Yellow River to the Caspian Sea, on which the Kuen-lun and the Thian-schan were drawn. As I think I have shown elsewhere (Asie Centrale, t. i. p. 118—129, 194—203, and t. ii. p. 413 to 425), it was these two ranges of mountains, and especially the first, which, when the march of the Macedonian armies brought the Greeks into nearer acquaintanceship with the interior of Asia, spread among their geographers the knowledge of a belt of mountains dividing the continent into two parts, and extending from Asia Minor to the Eastern Sea, from India and Scythia to Thinæ. (Strabo, lib. i. pag. 68, lib. xi. pag. 490.) Dicæarchus, and after him Eratosthenes, called this chain the prolongation of the Taurus. The Himalayas were included in this designation. Strabo says expressly (lib. xv. pag. 689), "India is bounded on the north, from Ariana to the Eastern Sea, by the extremities of the Taurus, which the natives call severally Paropamisos, Emodon, Imaon, and other names, but which the Macedonians call Caucasus." He had said previously (lib. xi. pag. 519), in the description of Bactriana and Sogdiana: "The last part of the Taurus, which is called Imaon, touches the Indian (Eastern ?) Sea." The names of "beyond" and "within the Taurus" referred to the belief in what was supposed to be a

single west and east chain. Strabo says: "The Hellenes term the half of Asia which slopes to the north the Hither Side of the Taurus, and that towards the south the Beyond Taurus" (lib. ii. p. 129). But in the later times of Ptolemy, when commerce, and especially the trade in silk, had become active, the name Imaus was transferred to a meridian chain, that of Bolor, as is shown by many passages in the sixth book. (Asie Centr. t. i. p. 146—162.) The line in which, according to Hellenic views, the Taurus mountains parallel to the equator were supposed to divide the whole continent, was first termed, by Dicæarchus a disciple of the Stagirite, "a diaphragm," or dividing-wall, because the geographical latitude of other points could be measured by perpendicular lines drawn to it. The Diaphragm was the parallel of Rhodes prolonged, to the westward to the Pillars of Hercules, and to the eastward to the coast of Thinæ. (Agathemeros, in Hudson's Geogr. Gr. Min. vol. ii. p. 4.) The Diaphragm, or "Divider," of Dicæarchus, alike interesting in geographical and in orographical respects, passed into the work of Eratosthenes, where he refers to it in the third book of descriptive geography, in explaining his table of the inhabited world. Strabo attaches so much importance to this line that (in lib. i. p. 65) he says: "Its eastern prolongation beyond Thinæ through the Atlantic Sea may possibly be the site of another inhabited world, or even of several worlds," though he does not, strictly speaking, predict the existence of such. It may excite surprise that he should use the word "Atlantic" instead of Eastern Sea, the name usually given to the Pacific Ocean; but as our Indian Sea south of Bengal is called in Strabo "the Atlantic South Sea," the two seas, which were assumed to unite on the south-east of India, were often confounded. Thus, in lib. ii. p. 130, it is said, "India, the greatest and most favoured of lands, which terminates at the Eastern Sea and at the Atlantic South Sea;" and in lib. xv. p. 689, "The southern and eastern sides of India, which are much greater than the other sides, run into the Atlantic Sea;" in which last passage, as well as in that before referred to relative to Thinæ (lib. i. p. 65), the expression of Eastern Sea seems even to be avoided. Having been constantly occupied, since the year 1792, with the "strike" and "dip" of mountain-strata, and with their relations to the geographical direction of the mountain-chains, I have thought that I ought to call attention to the circumstance that the mean parallel of latitude of the Kuen-lun, in its whole extent, as well as in its western prolongation through the Hindu Kho mountains, points to the basin of the Mediterranean and the Straits of Gibraltar (Asie Centr. t. i. p. 118—127, and t. ii. p. 115—118); and that the subsidence of the sea-bed in a great basin which is volcanic principally at its northern margin, may well be connected with those elevations and foldings My dear friend of many years, Élie de Beaumont, so profoundly acquainted

with all relations of geological direction, is, on grounds of "loxo dromismus," opposed to these views. (Notice sur les Systèmes de Montagnes, 1852, t. ii. p. 667.)

([568]) p. 415. — Kosmos, Bd. iv. S. 382 (English edition, p. 338).

([569]) p. 415. — Compare Arago, "Sur la cause de la dépression d'une grande partie de l'Asie et sur le phénomène que les pentes les plus rapides des chaînes de montagnes sont (généralement) tournées vers la mer la plus voisine," in his Astronomie populaire, t. iii. p. 1266—1274.

([570]) p. 416. — Klaproth, Asia polyglotta, p. 232; and Mémoires relatifs à l'Asie (taken from the Chinese Encyclopedia published by the orders of the Emperor Kanghi in 1711), t. ii. p. 342; Humboldt, Asie Centrale, t. ii. p. 125 and 135—143.

([571]) p. 416. — Pallas, Zoographia Rosso-Asiatica, 1811, p. 115.

([572]) p. 417. — Volcanic activity, instead of appearing in the Himalaya chain which is nearer to the sea (some parts of it, between the colossal Kinchinjinga and Schamalari, approach within 428 and 376 geogr. miles of the Bay of Bengal), does not show itself until the third inland parallel chain, the Thian-schan, almost four times as far; and it has there broken forth among very peculiar circumstances of neighbouring depressions which have overthrown strata and caused fissures. We know from the study, by Stanislas Julien, of Chinese geographical works, that the Kuen-lun, the northern boundary of Thibet, the Tsi-schi-schan of the Mongols, has, in the hill Schin-khieu, a hollow which sends forth a constant flame. (Asie Centrale, t. ii. p. 427—467 and 483.) This phænomenon appears to be quite analogous to that of the Chimæra of Lycia, so often referred to, which has burnt for thousands of years (see above, Note 375); it is not properly a volcano, but a "fire-spring," which diffuses to a distance a sweet-smelling odour (derived from naphtha (?)). The Kuen-lun, which Dr. Thomas Thomson, the learned botanist of Western Thibet (Flora Indica, 1855, p. 253), treats (just as I have done in my Asie Centrale, t. i. p. 127, and t. ii. p. 431) as a continuation of the Hindoo-Kho, with which the Himalaya, coming from the south-east, meets and unites, approaches so near to the last-mentioned chain at its western extremity, that my friend Adolph Schlagintweit regards "the Kuen-lun and Himalaya, on the west of the Indus, not as separate chains, but as forming one mass of mountains." (Report, No. IX., of the Magnetic Survey in India, by Adolph Schlagintweit, 1856, p. 61.) Throughout a distance which extends to 92° E. longitude, towards the "Starry Sea" or Lake of the Kuen-lun, as we learn by detailed descriptions drawn up in the seventh century under the dynasty of the Sui (Klaproth, Tableaux hist. de l'Asie, p. 204), forms an east and west parallel chain about $7\frac{1}{2}°$ of latitude

distant from the Himalaya. The brothers Hermann and Robert Schlagintweit were the first who, in the months of July to September 1856, succeeded in the adventurous attempt of proceeding frcm Ladak across the range of the Kuen-lun, and reaching the territory of Khotan. According to these always careful observers, the strike of the highest water-dividing range at the northern boundary of Thibet, and on which the Karakorum Pass, 18,300 feet high, is situated, is S.E.—N.W., therefore parallel to the portion of the Himalaya, which is over against it (*i. e.* that to the west of Dhawalagiri). The rivers of Yarkand and Karakasch, which form part of the great water-system of the Tarim and Lake Lop, take their rise on the north-eastern declivity of the Karakorum chain. From the area of this system of waters, the travellers passed over Kissilkorum, and by the Hot Springs (49° cent.,-110°·2 Fahrenheit), to the little Alpine lake of Kiuk-kiul in the east and west Kuen-lun range. (Report of Mag. Survey, No. VIII. Agra, 1857, p. 6.)

(573) p. 418.—Kosmos, Bd. i. S. 27, 48, 181; Bd. iv. S. 34—47, 164—169, and 369, mit Anm. 39 and 40 (English edition, vol. i. p. 27, 46, 131; present volume, Notes 33—47, 463, and 464).

(574) p. 418.—Arago (Astron. populaire, t. iii. p. 248) assumes almost the same thickness for the crust of the earth: 40,000 metres, about 5½ German geogr. miles, or 22 English; Élie de Beaumont (Systèmes de Montagnes, t. iii. p. 1237) makes the thickness one fourth greater. The earliest-made assumption was that of Cordier, in mean value 14 German or 56 English geographical miles: Hopkins's Mathematical Theory of Stability would require it to fall between 688 and 860 English geographical miles. On geological grounds, I fully concur with Naumann's doubts of so enormous a distance between the fluid interior and the craters of active volcanoes. See his excellent Lehrbuch der Geognosie, Bd. i. S. 62—64, 73—76, and 289.

(575) p. 419.—A very remarkable example of the manner in which appreciable alterations of composition may take place, through the gradual accumulation of very minute quantities, has been recently presented by Malagute's discovery, confirmed by Field, of the presence of silver in sea-water. Notwithstanding the enormous extent of the ocean, and the small surface of the hulls of the ships which traverse it, the trace of the silver in the sea-water has become perceptible on the copper-sheathing of vessels.

(576) p. 420.—Bunsen, Ueber die chemischen Prozesse der vulkanischen Gesteinsbildungen, Poggend. Annalen, Bd. lxxxiii. S. 242 and 246.

(577) p. 420.—Comptes rendus de l'Acad. des Sciences, t. xliii. 1856, p. 366 and 689. The first exact analysis of the gas which issues forth with noise from the great Solfatara of Pozzuoli, and which was collected with much diffi-

culty by Charles Sainte-Claire Deville, gave: of sulphurous acid (acide sulfureux), 24·5; oxygen, 14·5; and nitrogen, 61·4.

([578]) p. 420. — Kosmos, Bd. iv. S. 255—261. (English edition, present volume, p. 209—215).

([579]) p. 420. — Boussingault, Économie rurale (1851), t. ii. p. 724, 726: "La permanence des orages dans le sein de l'atmosphère (sous les tropiques) est un fait capital, parce qu'il se rattache à une des questions les plus importantes de la physique du globe, celle de la fixation de l'azote de l'air dans les êtres organisés. Toutes les fois qu'une série d'étincelles électriques passe dans l'air humide, il y a production et combinaison d'acide nitrique et d'ammoniaque. Le nitrate d'ammoniaque accompagne constamment l'eau des pluies d'orage, et comme fixe par sa nature il ne saurait se maintenir à l'état de vapeur; on signale dans l'air du carbonate ammoniacal, et l'ammoniaque du nitrate est amenée sur la terre par la pluie. Ainsi, en définitive, ce serait une action électrique, la foudre, qui disposerait le gaz azote de l'atmosphère à s'assimiler aux êtres organisés. Dans la zone équinoxiale, pendant l'année entière, tous les jours, probablement même tous les instants, il se fait dans l'air une continuité de décharges électriques. Un observateur placé à l'équateur, s'il était doué d'organes assez sensibles, y entendrait continuellement le bruit du tonnerre." But sal-ammoniac, as well as muriate of soda, is occasionally found, as a sublimation product of volcanoes, on streams of lava themselves: on Hecla, Vesuvius, and Etna; in the Guatemala volcanic chain (on the volcano of Izalco); and, above all, in Asia in the volcanic chain of the Thian-schan. The inhabitants of the district between Kutsch, Turfan, and Hami pay their tribute to the emperor of China in some years in sal-ammoniac (in Chinese nao-scha, in Persian nuschaden), which is an important article of foreign trade. (Asie Centrale, t. ii. p. 33, 38, 45, and 428.)

([580]) p. 421. — Viajes de Boussingault (1849), p. 78.

([581]) p. 421. — Kosmos, Bd. i. S. 295 and 469 (English edition, p. 270, and Note 326).

([582]) p. 422. — Rozet, Mémoire sur les Volcans d'Auvergne, in the Mémoires de la Soc. Géol. de France, 2e série, t. i. 1844, p. 64 and 120—130: "Les basaltes (comme les trachytes) ont percé le gneiss, le granite, le terrain houiller, le terrain tertiaire, et les plus anciens dépôts diluviens. On voit même les basaltes recouvrir souvent des masses de caillous roulés basaltiques; ils sont sortis par une infinité d'ouvertures dont plusieurs sont encore parfaitement (?) reconnaissables. Beaucoup présentent des cônes de scories plus ou moins considérables, mais on n'y trouve jamais des cratères semblables à ceux qui ont donné des coulées de laves. . . . . ."

([583]) p. 422. — Like the granitic pieces enveloped in the trachytes of Jorullo. Kosmos, Bd. iv. S. 345 (English edition, present volume, p. 300—301).

([584]) p. 422. — Also in the Eifel, according to the high authority of Berghauptmann von Dechen. Kosmos, Bd. iv. S. 281 (present volume, p. 235).

([585]) p. 422. — Kosmos, Bd. iv. S. 357 (present volume, p. 312). The Rio de Guaillabamba flows into the Rio de las Esmeraldas. The village of Guaillabamba, near which I found the isolated basalts containing olivine, is only 6908 feet above the sea. The heat in this valley is extremely oppressive, and it is still worse in the Valle de Chota, between Tusa and the Villa de Ibarra, of which the lowest part is only 5288 feet above the sea, and which may rather be called a deep cleft than a valley, being rather under 9600 feet wide, and fully 4800 feet deep. (Humboldt, Rec. d'Observ. astronomiques, vol. i. p. 307.) The eruption of fragments called Volcan de Ansango, on the declivity of Antisana, is not a formation of basalt; they consist of a trachyte containing oligoclase, and bearing some resemblance to a basalt. On the mutual avoidance, or "antagonisme des basaltes et des trachytes," see my Essai géognostique sur le gisement des Roches, 1823, p. 348 and 359, and, in general, p. 327—336.

([586]) p. 425. — Sébastien Wisse, Exploration du Volcan de Sangay, in the Comptes rendus de l'Acad. des Sciences, t. xxxvi. (1853) p. 721; compare also Kosmos, Bd. iv. S. 292, Anm. 40, and S. 301—303 (English edition, p. 248, and Note 364). According to Boussingault, the erupted fragments brought back by Wisse, and which were collected on the upper portion of the declivity of the cone (the traveller reached a height of 960 feet below the summit, which has itself a diameter of 486 feet), consist of a black pitch-like substance, in which are embedded crystals of glassy (?) felspar. A very remarkable phænomenon, unique, I believe, in volcanic eruptions, so far as we are at present aware, is that, together with these large black pieces of trachyte, small angular pieces of *pure quartz* are erupted. These fragments (according to a letter written, in January 1851, by my friend Boussingault) are not more than four cubic centimetres in volume. In the trachytic masses themselves there is no quartz interspersed. All volcanic trachytes which I have examined in the Cordilleras of South America and Mexico, and even those trachytic porphyries in which the rich silver-veins of Real del Monte, Moran, and Regla, north of the high valley of Mexico, occur, are *entirely without quartz.* Notwithstanding this apparent antagonism between quartz and trachyte in burning volcanoes, I am not inclined to deny the volcanic origin of the millstone trachytes (trachytes et porphyres meulières) to which Beudant has justly called attention. The manner in which these have burst forth from fissures is, however, doubtless a mode of

origin altogether different from the formation of conical or dome-shaped trachytic frameworks.

(587) p. 425.—Kosmos, Bd. iv. S. 276—280 (English edition, p. 230—234).

(588) p. 426.—The most complete account, based on actual measurements of heights and angles of inclination and on sections, which we possess for any volcanic district, is that which we owe to the fine investigations of the Olmütz astronomer Julius Schmidt, of Vesuvius, the Solfatara, the Monte Nuovo, the Astroni, Rocca Monfina, and the ancient volcanoes of the Papal States (in the Alban Hills, Lago Bracciano, and Lago di Bolsena); see Julius Schmidt's work, " Die Eruption des Vesuvs im Mai 1855;" and in the accompanying Atlas, Plates III., IV., and IX.

(589) p. 426. — In the progressive advances which have been made in our knowledge of the surface of the moon, from Tobias Mayer to Lohrmann, Mädler, and Julius Schmidt, the belief in the great analogies between the terrestrial and lunar volcanic frameworks has, on the whole, rather lessened than increased: not so much on account of relations of dimension and early recognised inter-arrangement of so many annular forms, as on account of the " rills " and of the " systems of rays," which cast no shadows, and are more than four hundred miles long, and from two to sixteen miles broad: as in Tycho, Copernicus, Kepler, and Aristarchus. It is interesting to notice that Galileo, in his letter to Pater Christopher Grienberger " Sulle Montuosità della Luna," compared the lunar Ring Mountains, whose diameters he believed to be greater than they really are, to the mountain-encircled land of Bohemia; and that the ingenious Robert Hooke, in his Micrographia, ascribed the circular type, which prevails so largely on the moon's surface, to the reaction of the interior of the lunar globe upon its exterior. (Kosmos, Bd. ii. S. 508; and Bd. iii. S. 508 and 544: English edition, vol. ii. p. 349; and vol. iii. p. 365, and Note 588.) In regard to the Ring Mountains of the moon, I have, in recent years, felt a lively interest in the question of the relative heights of the central mounts and the encircling ridges or crater-margins, and in the existence of parasitic craters on the encircling ridge itself. The result of all the careful observations of Julius Schmidt, who is engaged in continuing and completing Lohrmann's Topography of the Moon, is to the effect: — " That in no single case does the one central mount attain a height equal to that of its surrounding crater-wall; and that it is probable that in all cases the summit of the central mount is even considerably below the surface of the moon from which the crater has broken forth." Whereas the cone of scoriæ within the crater of Vesuvius, which rose up on the 22nd of October 1822, according to Brioschi's trigonometrical measurement passes the Punta del Palo (the high-

est part of the crater-margin) by about thirty feet, and can be seen from Naples, on the moon, on the contrary, many of the central mounts, as measured by Mädler and by Schmidt, are fully 1000 toises (about 6400 feet) lower than the mean height of the encircling ridge, and even 100 toises below what may be supposed to be the mean level of the general surface of that part of the moon. (Mädler, in Schumacher's Jahrbuch for 1841, S. 272 and 274; and Julius Schmidt's "Der Mond," 1856, S. 62.) The lunar central mounts, or it may perhaps rather be said "central masses of mountains," have usually several summits: as in Theophilus, Petavius, and Bulliald. There are six central mounts in Copernicus, while Alphons alone shows one regular central peak with a sharp-pointed summit. The above relations remind us of the Astroni in the Phlegræan Fields, to whose dome-shaped central masses Von Buch justly attributed great importance. "These masses (like the central masses in the Ring Mountains in the moon) did not burst forth; no permanent connection with the interior, no volcano was formed; but rather, as it were, a model on a small scale of those great trachytic unopened domes, as Puy de Dôme and Chimborazo, which are so variously distributed over the earth's surface." (Poggendorff's Annalen, Bd. xxxvii. 1836, S. 183.) The encircling margin of the Astroni has everywhere the form of a closed ellipse, never rising higher than 130 toises (831 feet) above the level of the sea. The summits of the central domes are 658 feet lower than the highest part of the south-western crater-wall. The domes form two parallel ridges clothed with thick bushes. (Julius Schmidt, "Eruption des Vesuvs," S. 147; and the same author's "Der Mond," S. 70 and 103.) One of the most remarkable objects on the moon's surface is the Ring Mountain Petavius, in which the whole interior crater-floor has expanded in a convex form, and yet is crowned by a central mount. The convexity, resembling a blister-like swelling, is here a permanent form. In our terrestrial volcanoes it is only temporarily that the crater-floor is sometimes so inflated by the force of the vapours beneath as to rise almost to the height of the crater-margin; but as the vapours break through and burst forth, the inflated floor sinks down again. The greatest diameters of terrestrial craters are those of the Caldeira de Fogo, according to Charles Deville 4100 toises (4·3 geogr. miles); and the Caldeira of Palma, according to Leopold von Buch, 3100 toises; whereas, on the moon, Theophilus is 50,000 toises, and Tycho 45,000 toises (or respectively 52 and 45·2 geogr. miles). Parasitical secondary craters, which have broken forth on a marginal wall of a great crater, are very frequent on the moon. The crater-floor in these parasites is usually empty, as on the great rent-asunder margin of Maurolycus; it is more rare to see a small central mount, perhaps a cone of eruption, as in Longomontanus. In a fine sketch of the crater-system of Etna,

sent to me, in August 1854, from Flensburg, by my friend the astronomer Christian Peters (now at Albany in North America), one can distinctly recognise the parasitical margin-crater (called Pozzo di Fuoco) which was formed on the E.S.E. side in January 1833, and had several strong eruptions of lava until 1843.

([590]) p. 427. — The little-characteristic indefinite name of trachyte (rough stone), which is now so generally given to the rock in which volcanoes break forth, was first applied by Hauy in 1822, in the second edition of his Traité de Minéralogie, vol. iv. p. 579, to a rock of Auvergne, and merely accompanied by a notice of the derivation of the name, and a short description in which there is no mention of the older designations: "granite chauffé en place" of Desmarets, "trap-porphyry," and "domite." Previously to 1822, however, the name had been known in verbal communications occasioned by Hauy's lectures in the Jardin des Plantes; and it appears in Von Buch's Memoir on Basaltic Islands and Elevation-Craters, published in 1818; in Daubuisson's Traité de Minéralogie, 1819; and in Beudant's important work, "Voyage en Hongrie." From friendly letters very recently received from Élie de Beaumont, the recollections of M. Delafosse, formerly Aide-Naturaliste to Hauy, and now Membre de l'Institut, would carry the use of the name back to between 1813 and 1816. The publication of the name "domite," by Von Buch, seems, according to Ewald, to belong to 1809; domite is first mentioned in the third letter to Karsten (Geognostische Beobachtungen auf Reisen durch Deutschland und Italien, Bd. ii. 1809, S. 244). It is there said: — "The porphyry of the Puy de Dôme is a peculiar kind of rock, hitherto without a name, consisting of felspar crystals with glassy lustre, hornblende, and black laminæ of mica. In the cracks and clefts of this rock, which I will call provisionally domite, there are fine drusic cavities whose walls are covered with crystals of ferruginous mica. In the whole length of the Puy, cones of domite alternate with cones of scoriæ." The second volume of the Travels, which contains the letters from Auvergne, was printed in 1806, but not published until 1809, which is therefore, strictly speaking, the date of the publication of the name. It is singular that in Von Buch's memoir four years later, "Ueber den Trapp-Porphyr," domite is no longer spoken of. In referring, in the text, to a profile of the Cordilleras contained in the journal of my travels for July 1802, extending from 4° N. to 4° S., and inscribed "Affinité entre le Feu volcanique et les Porphyres," my wish was to recall that it was this profile — which represents the three breakings-through of the volcanic groups of Popayan, Los Pastos, and Quito, and the outburst of trap-porphyry in the granite and mica-slate of the Paramo de Assuay (near the Cadlud Road, at a height of 15,526 feet), — which led Leopold von Buch to ascribe to me only too decidedly

and kindly the first recognition that "all the volcanoes of the Andes have their seat in a porphyry which is a peculiar rock, and belongs essentially to volcanic formations." (Abhandlungen der Akademie der Wiss. zu Berlin, for 1812—1813, S. 131, 151, and 153.) I may, indeed, have expressed the phænomenon with most generality; but, as early as 1789, Nose, whose merits were long unrecognised, had, in his "Orographic Letters," described the volcanic rock of the Siebengebirge as "a peculiar kind of Rhenish porphyry, nearly allied to basalt and porphyritic schist." He says that this formation is particularly characterised by glassy felspar, which he proposes to call sanidine, and that, by its age, it belongs to the middle-flœtz strata. (Niederrheinische Reise, Th. I. S. 26, 28, and 47; Th. II. S. 428.) I am inclined to think that Von Buch was mistaken in stating that Nose recognised this porphyritic formation (which he not very happily calls "granite-porphyry") and basalts as being younger than the most recent flœtz-strata. The great early-removed geognost said: "The whole rock ought to be named from the glassy felspar (therefore sanidine-porphyry), if it had not already the name of trap-porphyry." (Abh. der Berl. Akad. for 1812—1813, S. 134.) The history of the systematic nomenclature of a science is not without some importance, inasmuch as it reflects the succession of prevailing opinions.

([591]) p. 427. — Humboldt, Kleinere Schriften, Bd. i. Vorrede, S. iii.—v.

([592]) p. 428.—Leop. von Buch, in Poggendorff's Annalen, Bd. xxxvii. 1836, S. 188 and 190.

([593]) p. 428. — Gustav Rose in Gilbert's Annalen, Bd. 73, 1823, S. 173, and Annales de Chimie et de Physique, t. xxiv. 1823, p. 16. Oligoclase was first proposed as a new mineral species by Breithaupt. (Poggendorff's Annalen, Bd. viii. 1826, S. 238.) Subsequently oligoclase appeared to be identical with a mineral which Berzelius observed in a granite dyke in gneiss, near Stockholm, and which, on account of similarity of chemical composition, he had called "Natron Spodumen." (Poggendorff's Ann. Bd. ix. 1827, S. 281.)

([594]) p. 429.—See Gustav Rose on the granite of the Riesengebirge, in Pogg. Ann. Bd. lvi. 1842, S. 617. Berzelius had only found oligoclase, his "Natron Spodumen," in a granite dyke; it is in the above-cited memoir that it is first spoken of as an ingredient of granite (of the rock itself). Gustav Rose determined oligoclase by its specific weight, the larger quantity of lime contained in it in comparison with albite, and its greater fusibility. A specimen, of which he had found the specific gravity 2·682, was analysed by Rammelsberg. (Handwörterbuch der Mineral. Suppl. i. S.104; and G. Rose, Ueber die zur Granitgruppe gehörenden Gebirgsarten, in der Zeitschr. der Deutschen geol. Gesellschaft, Bd. i. 1849, S. 364.)

([595]) p. 430.—Rozet, sur les Volcans de l'Auvergne, in the Mém. de la Soc. Géologique de France, 2ème Série, t. i. p. i. 1844, p. 69.

([596]) p. 430.—Fragments of leucite-ophyr, collected by me on Monte Nuovo, have been described by Gustav Rose in Fried. Hoffmann's Geognostischen Beobachtungen, 1839, S. 219. On the trachytes of the Monte di Procida, in the island of the same name, and on the rocky shoal of S. Martino, see Roth, Monographie des Vesuvs, 1857, S. 519—522, Tab. viii. The trachyte of the island of Ischia contains, in the Arso or lava-current of Cremate (1301), glassy felspar, brown mica, green augite, magnetic iron, and olivine (S. 528); no leucite.

([597]) p. 430.—The geologo-topographical relations of the Siebengebirge near Bonn have been developed and described, with generalising sagacity and great exactness, by my friend Berghauptmann H. von Dechen, in the 9th year's series of the Verhandlungen des natur-historischen Vereines der preus. Rheinlande und Westphalens, 1852, S. 289—567. All the chemical analyses of the trachytes of the Siebengebirge which have yet appeared are collected there (S. 323—356): and some account is given of the trachytes of the Drachenfels and Röttchen, in which, besides the large crystals of sanidine, many small crystalline particles can be distinguished in the ground mass. "These were recognised by Dr. Bothe, by chemical analyses performed in Mitscherlich's laboratory, to be oligoclase; in entire agreement with the oligoclase of Danvikszoll (near Stockholm), cited by Berzelius." (Dechen, S. 340—346.) The Wolkenberg and the Stenzelberg are without glassy felspar (357 and 363), and belong not to the second division but to the third; they present a Toluca rock. Many new views are contained in the section of the "Geognostischen Beschreibung des Siebengebirges," which treats of the relative age of trachytic and basaltic conglomerates (S. 405—461). "Besides the more rare dykes of trachyte, in the trachytic conglomerates, which show that after the deposition of the conglomerate the formation of trachyte still continued to take place (S. 413), there are frequent dykes of basalt (416). The formation of basalt decidedly comes down to a later period than that of trachyte, and the principal mass of basalt is here younger than the trachyte. On the other hand, it is only a portion of this basalt,—not all basalt (S. 323),—which is younger than the great mass of the brown coal. The two formations, basalt and brown coal, run into each other in the Siebengebirge, as in so many other places, and are to be looked upon, on the whole, as contemporaneous." Where very small crystals of quartz appear as a rarity in the trachytes of the Siebengebirge, as they do according to Noggerath and Bischof in the Drachenfels and in the Rhondorfer Thal, they fill cavities, and seem to be of later formation (S. 361 and 370): perhaps they have been produced by the weathering of the sanidine. On Chimborazo I once saw similar but very thin

depositions of quartz on the sides of the cavities in some very porous brick-red trachytic masses, at an elevation of about 17,000 feet. (Humboldt, Gisement des Roches, 1823, p. 336.) These pieces, which are repeatedly mentioned in my journal, are not in the Berlin collections. Weathering of oligoclase, or of the whole ground-mass of the rock, may also give rise to such traces of free silicic acid. Some points in the Siebengebirge still deserve fresh and persevering examination. The highest summit, the Löwenberg, spoken of as basalt, appears, by the analysis of Bischof and Kjerulf, to be a doleritic rock. (H. von Dechen, S. 383, 386, and 393.) The rock of the little Rosenau, which has sometimes been called Sanidophyr, belongs, according to G. Rose, to the first division of his trachytes, and is very nearly related to trachytes of the Ponza Islands. The trachyte of the Drachenfels, with large crystals of glassy felspar, appears to resemble most nearly (according to Abich's observations, which unfortunately are not yet published) that of Dsyndserly dagh, 8500 feet high, which rises to the north of the great Ararat, out of a nummulite formation, having underlying Devonian strata.

([598]) p. 431.—The near vicinity of Cape Perdica, on the island of Ægina, to the brownish-red Trœzene-trachytes of the peninsula of Methana (Kosmos, Bd. iv. S. 273, Anm. 86; English edition, p. 227, and Note 310), and to the sulphur-springs of Bromolimni, renders it probable that the trachytes of Methana, as well as those of the island of Kalauria, near the little town of Poros, belong to the same third division of G. Rose (oligoclase, with hornblende and mica). Kurtius, Peloponnesos, Bd. ii. S. 439 and 446, Tab. xiv.

([599]) p. 431.—See the excellent geological map of the country round Schemnitz, by Bergrath Johann von Peltko, 1852, and the Abhandl. der k. k. geologischen Reichsanstalt, Bd. ii. 1855, Abth. i. S. 3.

([600]) p. 431.—Kosmos, Bd. iv. S. 427, Anm. 7 ; English edition, p. 386, and Note 531.

([601]) p. 431.—The basaltic columns of Pisoje, the felspathic part of which has been analysed by Francis (Poggend. Annalen, Bd. lii. 1841, S. 471), and which are situated near the bank of the Cauca River, in the plains of Amolanga (not far from the Pueblos de Sta. Barbara and Marmato), consist of a somewhat altered oligoclase in large fine crystals, and small crystals of hornblende. Nearly allied to this mixture are: the quartz-containing diorite-porphyry of Marmato, brought home by Degenhardt, and in which Abich called the felspathic constituent Andesin; the rock without quartz of Cucurusape, near Marmato, from Boussingault's collection (Charles Sainte-Claire Deville, Études de Lithologie, p. 29); the rock which I found in situ twelve geographical miles east of Chimborazo, under the ruins of Old Riobamba (Humboldt, Kleinere Schriften, Bd. i. S. 161);

and lastly, the rock of the Esterel Mountains, in the Départ. du Var (Élie de Beaumont, Explic. de la Carte géol. de France, t. i. p. 473).

([602]) p. 432. — The felspar in the trachytes of Teneriffe was first recognised in 1842, by Charles Deville, who visited the Canary Islands in the autumn of that year. See that distinguished geologist's Voyage géologique aux Antilles et aux Iles de Ténériffe et de Fogo, 1848, p. 14, 74, and 169; and his Analyse du Feldspath de Ténériffe in the Comptes rendus de l'Acad. des Sc. t. xix. 1844, p. 46. He says, "Les travaux de Messrs. Gustav Rose et H. Abich n'ont pas peu contribué sous le double point de vue crystallographique et chimique, à répandre du jour sur les nombreuses variétés de minéraux qui étaient comprises sous la vague dénomination de feldspath. J'ai pu soumettre à l'analyse des cristaux *isolés avec soin* et dont la densité en divers échantillons était très-uniformément, 2·593, 2·594, et 2·586. C'est la première fois que le feldspath oligoclase a été indiqué dans les terrains volcaniques, à l'exception peut-être de quelques-unes des grandes masses de la Cordillère des Andes. Il n'avait été signalé, au moins d'une manière certaine, que dans les roches éruptives anciennes (plutoniques, granites, syénites, porphyres syénitiques . . . .); mais dans les trachytes du Pic de Ténériffe il joue un rôle analogue à celui du labrador dans les masses doléritiques de l'Etna." Compare also Rammelsberg, in the Zeitschrift der deutschen geologischen Gesellschaft, Bd. v. 1853, S. 691, and the 4th Supplement to Handwörterbuch der chemischen Mineralogie, S. 245.

([603]) p. 432.—The first determination of the height of the great volcano of Mexico, Popocatepetl, is, so far as I am aware, the trigonometric measurement made by me on the 24th of January 1804, in the Llano de Tetimba. The summit was found to be 1536 toises above the Llano, and as the latter is, according to barometrical determination, 1234 toises above the coast of Vera Cruz, we have the absolute height of the volcano 2770 toises, or 17,713 feet. The barometric measurements which followed my trigonometrical determination, led to the conjecture that the height of the volcano was still greater than that stated by me in the Essai sur la Géographie des Plantes, 1807, p. 148, and in the Essai politique sur la Nouv. Espagne, t. i. 1825, p. 185. William Glennie, who, on the 20th of April 1827, was the first to reach the margin of the crater, found the height, according to his own calculation (Gazeta del Sol, publ. en Mexico, No. 1432), 17,884 English feet (2796 toises); or, according to a correction by Oberbergrath Burkart, who has done so much for American hypsometry, and by comparison with an almost simultaneous barometric observation at Vera Cruz, even 18,011 feet. A barometric measurement by Samuel Birkbeck (10th Nov. 1827), calculated according to Oltmann's tables, again gave, however, 17,854 feet, and the measurement of Alexandre Doignon (Gumprecht, Zeitschrift

für allg. Erdkunde, Bd. iv. 1855, S. 390), in almost too courteous agreement with my Tetimba measurement, 5403 metres, =17,725 feet. The present accomplished Prussian Envoy at Washington, Herr von Gerolt, has also been on the top of Popocatepetl, accompanied by Baron Gros (28th May 1833), and by an exact barometric measurement found the height of the Roca del Fraile below the crater 16,892 feet above the sea. A remarkable difference from the above-named hypsometric results, which have been stated in chronological order, is presented by what appears to be a very carefully made barometric measurement by M. Craveri, published in Petermann's valuable Mittheilungen über wichtige neue Erforschungen der Geographie, 1856 (Heft x.), S. 358—361. This traveller, in September 1855, found the elevation of the highest, *i. e.* of the north-westernmost crater-margin, as compared with what he considered to be the mean atmospheric pressure at Vera Cruz, only 5230 metres, =16,099 French feet; being 521 such feet ($\frac{1}{32}$ of the whole height measured) *less* than I had found by trigonometric measurement half a century before. Craveri also considers the height above the sea of the city of Mexico to be 184 French feet less than it was made by Burkart and myself at very different periods (instead of 2277 metres, he estimates it at only 2217 metres). I have treated more fully of these variations, in plus and minus, from the result of my trigonometric measurement (which unfortunately has not even yet been followed by a second one), in the above-named Journal of Dr. Petermann, S. 479—481. The 453 determinations of elevation which I made from September 1799 to February 1804, in Venezuela, on the forest-covered banks of the Orinoco, Rio de la Magdalena, and Amazons; in the Cordilleras of New Granada, Quito, and Peru; and in the tropical parts of Mexico; which have all been recalculated by Professor Oltmanns, uniformly according to the formula of Laplace with the coefficients of Ramond, and which were published, in 1810, in my "Nivellement barométrique et géologique" (Recueil d'Observ. astronomiques, vol. i. p. 295—334), were made without exception with Ramsden's cistern-barometers, "à niveau constant," and not at all with apparatus in which one inserts successively several fresh-filled Torricellian tubes, nor with the instrument described by me in Lamétherie's Journal de Physique, t. iv. p. 468, and which was only occasionally employed in Germany and France in the years 1796 and 1797. I used similarly constructed Ramsden's portable cistern-barometers in 1805, in a journey through Italy and Switzerland with Gay-Lussac; we were both satisfied with their performance, and a comparison with results obtained in the excellent investigations of Julius Schmidt (Beschr. der Eruption des Vesuvs im Mai 1855, S. 114—116) has recently shown that we had reason to be so. As I never ascended the summit of Popocatepetl, but measured it trigonometrically, it is the more diffi-

cult to understand the grounds of the extraordinary objection made by Craveri, in Petermann's Geogr. Mittheil. Heft x. S. 359: "that the height ascribed by me to the mountain is too small, because, as I have myself stated, I had employed the method of setting up fresh-filled Torricellian tubes." The apparatus with several tubes is not applicable in the open air, and least of all on the summit of a high mountain. It is one of the means to which, with the conveniences that cities afford, an observer may have recourse at long intervals of time, when he is uneasy as to the condition of his barometer. In this way, as a means of verification, I have had recourse to it on a few very rare occasions only, but I would still recommend it to travellers as warmly as I did in my Observ. astr. (vol. i. p. 363 — 373): "Comme il vaut mieux ne pas observer du tout que de faire de mauvaises observations, on doit moins craindre de briser le baromètre que de le voir dérangé. Comme nous avons, M. Bonpland et moi, traversé quatre fois les Cordillères des Andes, les mesures qui nous intéressaient le plus ont été répétées à différentes reprises; on est retourné aux endroits qui paraissaient douteux. On s'est servi de temps en temps de *l'appareil de Mutis*, dans lequel on fait l'expérience primitive de Torricelli, en appliquant successivement trois ou quatre tubes fortement chauffés, remplis de mercure récemment bouilli dans un creuset de grès. Lorsqu'on est sûr de ne pas pouvoir remplacer les tubes, il est peut-être prudent de ne pas faire bouillir le mercure dans ces tubes mêmes. C'est ainsi que j'ai trouvé, dans des expériences faites conjointement avec M. Lindner, professeur de chimie à l'école des mines du Mexique, la hauteur de la colonne de mercure à Mexico, dans six tubes de —

259·7	lignes	(ancien pied de Paris).
259·5	"	"
259·9	"	"
259·9	"	"
260·0	"	"
259·9	"	"

Les deux derniers tubes seuls avaient été purgés d'air au feu par M. Bellardoni, ingénieur d'instruments à Mexico. Comme l'exactitude de l'expérience dépend en partie de la propreté intérieure des tubes vides, si faciles à transporter, il est utile de les fermer hermétiquement à la lampe." As in mountainous districts the angles of altitude for trigonometrical measurements cannot be taken from the sea-shore, and the measurements themselves are mixed, being in part barometric (often they are so to a third, and from that to a half of their whole amount), the determination of the elevation of the high plain in which the base line is measured becomes of great importance. As corresponding barometric observations at sea are rare, and in most cases too distant, travellers are only

too much disposed to assume, as the mean atmospheric pressure on the high plain and at the sea-shore, results inferred by them from observations made during a few days only, and perhaps also at other seasons. "Dans la question de savoir, si une mesure faite au moyen du baromètre peut atteindre l'exactitude des opérations trigonométriques, il ne s'agit que d'examiner, si dans un cas donné les deux genres de mesures ont été faites dans des circonstances également favorables, c'est-à-dire, en remplissant les conditions que la théorie et une longue expérience ont prescrites. Le géomètre redoute le jeu de refractions terrestres; le physicien doit craindre la distribution si inégale et peu simultanée de la température dans la colonne d'air, aux extrémités de laquelle se trouvent placés les deux baromètres. Il est assez probable que près de la surface de la terre le décroissement du calorique est plus lent qu'à de plus grandes élévations; et pour connaître avec précision la densité moyenne de toute la colonne d'air, il faudrait, en s'élevant dans un ballon, pouvoir examiner la température de chaque tranche ou couche d'air superposée." (Humboldt, Recueil d'Observ. astron. vol. i. p. 138 and 371, in the Memoir on Refraction and barometric Measurements.) While, on the one hand, the barometric measurement of Messrs. Truqui and Craveri gives only 17,158 feet for the height of Popocatepetl, and, on the other, Mr. Glennie's makes it 17,884 feet, a newly published result, by a traveller who has examined the environs of Mexico and the districts of Yucatan and Chiapa (Gymnasial-Professor Carl Heller of Olmütz), agrees with mine to within thirty-two feet. (Compare my memoir entitled "Ueber die Höhe des mexicanischen Vulkans Popocatepetl," in Dr. Petermann's Mittheilungen aus Justus Perthes geographischer Anstalt, 1856, S. 479—481.)

(604) p. 432. — In the Chimborazo-rock it is not possible to separate mechanically the crystals of felspar from the ground-mass in which they are embedded, as can be done in the Etna-rock; but the proportionally large amount of silicic acid contained, and the lower specific gravity of the rock connected therewith, enable the felspathic ingredient to be recognised as oligoclase. The amount of silicic acid contained, and the specific weight, are, for the most part, in inverse proportion: in oligoclase and labradorite respectively the first is 64 and 53 per cent, while the latter is 2·66 and 2·71. Anorthite has, with only 44 per cent of silicic acid, the great specific gravity of 2·76. In felspathic minerals, which are also isomorphous, this inverse ratio, between the amount of silicic acid and the specific gravity, does not hold good with different forms of crystals, as Gustav Rose has remarked. Thus, for example, felspar and leucite have the same constituents—potash, alumina, and silicic acid; but felspar has 65, and leucite only 56 per cent of silicic acid; and yet the former has a higher specific gravity (2·56) than the latter (2·48).

As, in the spring of 1854, I wished for a new analysis of the Chimborazo

trachyte, Professor Rammelsberg was so kind as to undertake it, with his usual precision. I subjoin the results as they were communicated to me by Gustav Rose in a letter in the month of June 1854. "The piece of Chimborazo-rock, which Professor Rammelsberg has submitted to a careful analysis, was broken off from a specimen in your collection, which you had brought from the narrow rocky crest at an elevation of 19,094 feet above the sea.

"ANALYSIS BY RAMMELSBERG.

(*Elevation*, 19,094 *English feet; specific gravity*, 2·806.)

		Oxygen.		
Silicic acid - -	59·12		30·70	2·33
Alumina - - -	13·48		6·30	1·0
Protoxyde of iron	7·27	1·61		
Lime - - -	6·50	1·85		
Talc - - -	5·41	2·13	6·93	
Soda - - -	3·46	0·89		
Potash - - -	2·64	0·45		
	97·88			

"ANALYSIS BY ABICH.

(*Elevation*, 16,178 *English feet; specific gravity*, 2·685.)

		Oxygen.		
Silicic acid - -	65·09		33·81	2·68
Alumina - - -	15·58		7 27	
Oxyde of iron - -	3·83		1·16	
Protoxyde of iron -	1·73		0·39	
Lime - - -	2·61		0·73	1·0
Talc - - -	4·10		1·58	
Soda - - -	4·46		1·14	
Potash - - -	1·99		0·33	
Loss - - -	0·41			
	99·80			

"(In explanation of the above numbers, it is to be remarked that the first column gives the per-centage of the different constituents, and the second and third the amount of oxygen in them. The second column indicates only the oxygen of the stronger oxydes (which contain 1 atom of oxygen). In the third column this is collected together, for the sake of comparison with the alumina (which is a weak oxyde) and the silicic acid. The fourth column gives the proportion of the oxygen of the silicic acid to the oxygen of all the bases taken together as = 1. In the Chimborazo-trachyte this proportion is = 2·33 : 1·0.)

" The differences between the analyses of Rammelsberg and Abich are, indeed, rather considerable. Both the specimens of Chimborazo-rock analysed, one from an elevation of 19,094 feet, and the other from 16,178 feet, were struck off by yourself, and are from your geognostical collection in the Royal Cabinet of Minerals in Berlin. The rock from the lesser elevation (scarcely 400 feet higher than the summit of Mont Blanc), which was analysed by Abich, has a lower specific gravity, and, in accordance therewith, a greater amount of silicic acid than the rock from the higher elevation which was analysed by Rammelsberg. Assuming the alumina to belong exclusively to the felspathic portion, we may reckon in Rammelsberg's analysis : —

Oligoclase - - -	58·66
Augite - - - -	34·14
Silicic acid - - -	4·08

As with the assumption of oligoclase there thus still remains over some free silicic acid, it is probable that the felspathic ingredient is oligoclase, and not labradorite. This latter does not present itself with free silicic acid; and with the assumption of labradorite in the rock, there would remain over still more silicic acid."

A careful comparison of many analyses — for which I am indebted to the friendship of M. Charles Sainte-Claire Deville, who had the free chemical use of any part of the rich geological collections of our common friend Boussingault — shows that the quantity of silicic acid, in the ground-mass of trachytic rocks, is mostly greater than in the felspars which they contain. The subjoined table, kindly communicated to me by the author, in the month of June 1857, includes five of the great volcanoes of the Andes.

Names of the Volcanoes.	Structure and Colour of the Mass.	Silicic Acid in the whole Mass.	Silicic Acid in the Felspar alone.
Chimborazo	half-vitrified, brownish grey	65·09 Abich	58·26
	half-vitrified and black -	63·19 Deville	
	crystalline grey - -	62·66 Deville	
Antisana	grey-black - - -	64·26 Abich	58·26
	- - - - - -	63·23 Abich	
Cotopaxi	glassy and brownish - -	69·28 Abich	
	granular - - - -	63·98 Abich	
Pichincha	black, glassy - - -	67·07 Abich	
Puracé	almost bottle-green - -	68·80 Deville	55·40
Guadeloupe	grey, granular, and cellular	57·95 Deville	54·25
Bourbon	crystalline, grey, porous -	50·90 Deville	49·06

"Ces différences, quant à la richesse en silice, entre la pâte et le feldspath," adds Charles Deville, "paraîtront plus frappantes encore, si l'on fait attention qu'en analysant une roche en masse, on analyse, avec la pâte proprement dite, non seulement des fragments de feldspath semblables à ceux que l'on en a extraits, mais encore des minéraux qui, comme l'amphibole, la pyroxène, et surtout le péridot, sont moins riches en silice que le felspath. Cet excès de silice se manifeste *quelquefois* par des grains isolés de quartz, comme M. Abich les a signalés dans les trachytes du Drachenfels, et comme moi-même j'ai eu l'occasion de les observer avec quelque étonnement dans le dolérite trachytique de la Guadeloupe."

"If," says Gustav Rose, "we add to the remarkable table of the quantity of silicic acid in the Chimborazo-rock the result of Rammelsberg's latest analysis (May 1854), we find that Deville's result falls just intermediate between those of Abich and Rammelsberg. We obtain:—

Chimborazo-rock.

Silicic acid	65·09	Abich (specific gravity, 2·685).
	63·19	Deville.
	62·66	Deville.
	59·12	Rammelsberg (specific gravity, 2·806)."

In a newspaper appearing at San Francisco, in California, "l'Écho du Pacifique," there is an account, on the 5th of January 1857, from a French traveller, Monsieur Jules Remy, of his having succeeded, on the 3rd of November 1856, in company with an Englishman, Mr. Brencklay, in reaching the summit of Chimborazo. He adds, "so wrapped in mist that as we mounted we were not aware of it (sans nous en douter)." He observed the boiling point of water at 77°·5 cent., the temperature of the air being 1°·7 cent., and on calculating the elevation from hence, "according to a hypsometric rule tested during repeated journeys in the Sandwich Islands," he was surprised at the result he obtained. He found that he had been at a height of 6543 metres (21,470 feet), differing only forty French feet from that given for the top of Chimborazo by my trigonometric measurement, taken in June 1803, from near Riobamba Nuevo, in the high plain of Tapia. This agreement between a trigonometric measurement, and one founded on the boiling point of water, is the more surprising, because my result involved, as must always be the case in the Cordilleras, a barometric portion (for the height of the plain of Tapia, 9484 feet), which for want of corresponding observations on the sea-shore, could not have all the accuracy that might be desired. (For details, see my Recueil d'Observ. astron. vol. i. p. lxxii. and lxxiv.) Professor Poggendorff kindly undertook the trouble

of examining what would be the result given by a more satisfactory mode of calculation under the most probable suppositions. Calculating under the two hypotheses of the temperature of the air at the sea-shore having been either $27^{\circ}\cdot5$ cent. or $26^{\circ}\cdot5$ cent., and the height of the barometer reduced to the freezing point 760^{mm} 0, he found, according to Regnault's Tables, that $77^{\circ}\cdot5$ cent. for the boiling point of water on the summit corresponds to a barometer reading of 320^{mm} 20 at 0° cent.; the temperature of the air was $+1^{\circ}\cdot7$ cent., which we may take for convenience as $1^{\circ}\cdot5$. According to these data, Oltmann's tables give for the height attained, in the first hypothesis ($27^{\circ}\cdot5$ cent.), 7328^{m} 2, and in the second hypothesis ($26^{\circ}\cdot5$ cent.), 7314^{m} 5, or, on the mean, 777 metres more than my trigonometric measurement. To have agreed with this last, the experiment, supposing the summit of Chimborazo to have been really attained, should have given the boiling point $2^{\circ}\cdot25$ cent. higher than it did. (Poggendorff's Annalen, Bd. 100, 1857, S. 479.)

(605) p. 433.—As early as 1833, when placing the rich Sicilian collections of Friedrich Hoffmann in the Berlin Mineralogical Cabinet, Gustav Rose satisfied himself and his friends that the trachytes of Etna contain labradorite. In the Memoir on the Rocks designated as greenstone and greenstone-porphyry (Poggend. Ann. Bd. 34, 1835, S. 29), Gustav Rose mentions Etna lavas which contain augite and labradorite. (Compare also Abich, in the fine Memoir on the whole felspar family, 1840, in Poggend. Ann. Bd. 50, S. 347.) Leopold von Buch calls the Etna-rock analogous to the dolerite of the Basalt formation. (Poggend. Bd. 37, 1836, S. 188.)

(606) p. 433. — Sartorius von Waltershausen, who has been for many years a diligent explorer of the trachytes of Etna, makes the important remark: "That hornblende there belongs rather to the older masses, the greenstone dikes in the Val del Bove, and the white and reddish trachytes which form the base of Etna in the Serra Giannicola. Black hornblendes and bright leek-green augites are there found near together. The more recent lava-streams from 1669 (particularly those of 1787, 1809, 1811, 1819, 1832, 1838, and 1842) show augite, but not hornblende, which appears to be produced under a slower rate of cooling." (Waltershausen, Ueber die vulkanischen Gesteine von Sicilien und Island, 1853, S. 111—114.) In the augite-containing trachytes of the Fourth Division, in the chain of the Andes, I have found augite abundant, but in some cases absolutely no crystals of hornblende, and in some others (as on Cotopaxi at an elevation of 14,068 feet, and on Rucu Pichincha at an elevation of 15,304 feet) a few interspersed rare but distinct black crystals of hornblende.

(607) p. 433. — Compare Pilla, in the Comptes rendus de l'Acad. des Sc. t. xx. 1845, p. 324. In the leucite-crystals of the Rocca Monfina, Pilla found

the surface covered with worm-tubes (serpuleæ), which indicates *submarine* volcanic origin. On the leucite-rock of the Eifel in the trachyte of the Burgberg near Rieden, and that of Albano, Lago Bracciano and Borghetto, north of Rome, see Kosmos, Bd. iv. S. 32, Anm. 93 (English edition, Note 317). In the centre of a large crystal of leucite, Leopold von Buch has often found the fragment of a crystal of augite, around which the leucitic crystallisation has taken place, "which, as has been already remarked, seems somewhat strange, viewing the easy fusibility of augite and the non-fusibility of leucite. It is still more frequent to find pieces of the paste of the leucite-porphyry itself enclosed as a nucleus." Olivine is also found in lavas: as in the cavities of the obsidian which I brought from Mexico from the Cerro del Jacal (Kosmos, Bd. i. S. 464, Anm. 60); and yet it is also found in the hypersthene-rock of Elfdal, which was long taken for syenite. (Berzelius, Sechster Jahresbericht, 1827, S. 302.) Oligoclase presents a similar contrast in respect to the places in which it is found: it occurs in the trachytes of still burning volcanoes (Peak of Teneriffe and Cotopaxi); and yet it presents itself also in the granite and granitite of Schreibersau and Warmbrunn in the Silesian Riesengebirge. (Gustav Rose, On the Rocks belonging to the Granite Group, in the Zeitschrift der deutschen geol. Gesellschaft zu Berlin, Bd. i. S. 364.) It is not so with leucite in Plutonic rocks; for the statement that leucites are found interspersed in the mica-slate and gneiss of the Pyrenees at Gavarnie (which has even been repeated by Hauy), has been found by Dufrénoy, by several years of local examination, to be erroneous. (Traité de Minéralogie, t. iii. p. 399.)

([608]) p. 435. — In a geological journey, which I made in 1795, through the south of France, the west of Switzerland, and the north of Italy, I had been convinced that the Jurassic limestone which Werner reckoned as belonging to his Muschelkalk, constituted a distinct formation. In my memoir on subterranean gases, which my brother, Wilhelm von Humboldt, published in 1799, while I was in South America, this formation, which I had designated provisionally as Jura-limestone, was first mentioned (S. 39). It was thence immediately adopted into Oberbergrath Karsten's "Mineralogische Tabellen," which were then much read. (1800, S. 64, and Vorrede, S. vii.) I had not named any of the fossils which characterise the formation, and respecting which Leopold von Buch did such valuable service in 1839; I was also mistaken in the age which I assigned to it, as from the neighbourhood of the Alps, which were then believed to be older than Zechstein, I supposed it to be older than the Muschelkalk. In the earliest Tables of Buckland, "On the Superposition of Strata in the British Islands," the "Jura-limestone" of Humboldt is reckoned as belonging to the

upper oolite. Compare my Essai géogn. sur le Gisement des Roches, 1823, p. 281.

([609]) p. 436. — The name of Andesite was first printed in a memoir of Leopold von Buch's, read at the Berlin Academy on the 26th of March 1835. As that great geologist restricted the name of trachyte to rocks in which glassy felspar is contained, he said in his memoir read to the Academy in March 1835, but not published until 1836 (Poggend. Ann. Bd. xxxvii. S. 188—190): — "The discoveries of Gustav Rose on felspar have thrown a new light on volcanoes and the whole of geognosy, and the kinds of rock in volcanoes have appeared thereby in a new and entirely unexpected aspect. After many careful examinations in the district about Catania, and on Etna, we, *i. e.* Elie de Beaumont and I, became convinced that there is no felspar in Etna, and therefore no trachyte. All the streams of lava, as well as the beds in the interior of the mountain, consist of a mixture of augite and labradorite. Another important difference in the rocks of volcanoes appears when albite takes the place of felspar; a new rock is thus constituted which can no longer be termed trachyte. According to G. Rose's investigations (at that time), it may be affirmed almost decidedly that not one of the numerous volcanoes of the Andes consists of trachyte; but that they all contain, in the mass of which they are formed, albite. Such an assertion seems a very bold one; but it will appear less so if we consider that almost the half of these volcanoes, and their products in either hemisphere, are known to us by Humboldt's travels alone. Further, this kind of rock, rich in albite, is known through Meyen in Bolivia and the north of Chili, through Pöppig to the extreme south of Chili, as well as through Erman in the volcanoes of Kamtschatka. Such a marked and widely extended prevalence seems sufficient to justify the name of andesite, by which this kind of rock, consisting of predominating albite mixed with a little hornblende, has been already more than once presented to notice." Almost at the same time, in the additions with which, in 1836, he so materially enriched the French edition of his work on the Canaries, Leopold von Buch entered into still further details; considering the volcanoes Pichincha, Cotopaxi, Tungurahua, and Chimborazo all to consist of andesite; and, on the other hand, calling the Mexican volcanoes true (sanidine-containing) trachytes! (Description physique des Iles Canaries, 1836, p. 486, 487, 490. and 515.) The lithological classification of the Mexican and Andes volcanoes which has been given in this work, shows that there is no such uniformity of mineralogical constitution, and that no general designation, taken from an extensive region of the earth, can be scientifically applicable. Not long afterwards, I also twice committed the fault of employing the name of andesite, the use of which tends to create confusion: once, in 1836, in the description of my attempt

to reach the summit of Chimborazo, printed in Schumacher's Jahrbuch for 1837, S. 204 and 205 (and reprinted in my Kleinere Schriften, Bd. i. S. 160 and 161); and the second time, in 1837, in a memoir on the Highland of Quito, in Poggend. Ann. Bd. xl. S. 165. I there said, having previously strongly opposed my friend's statement that all the volcanoes of the Andes are similarly constituted:— "Very recent times have shown that the different zones do not always present the same (mineralogical) composition,—the same ingredients. Sometimes we have trachytes proper characterised by glassy felspar, as at the Peak of Teneriffe and the Siebengebirge near Bonn, where some albite is associated with the felspar: these are felspar-trachytes, which, as active volcanoes, frequently produce obsidian and pumice; — sometimes melaphyres and doleritic compositions of labradorite and augite, more nearly approaching basalt: as at Etna, Stromboli, and Chimborazo; — sometimes albite with hornblende prevails: as in the newly so-called Andesites of Chili, and the magnificent columns of Pisoje, described as diorite-porphyry, near Popayan, at the foot of the Volcano of Puracé, or in the Mexican Volcano of Jorullo; — and lastly, sometimes leucite-ophyrs, mixtures of leucite and augite: as in the Somma, the old wall of the crater of elevation of Vesuvius." By an accidental misunderstanding of this passage, which bears many traces of the imperfect state of knowledge at that time (still assigning felspar instead of oligoclase to the Peak of Teneriffe, labradorite to Chimborazo, and albite to the Volcano of Toluca), the ingenious investigator Abich, himself both a chemist and a geologist, erroneously attributed to me (Poggend. Ann. Bd. li. 1840, S. 523) the invention of the name andesite as that of a trachytic, widely diffused, albite-containing rock; and gave to a new species of felspar, first analysed by him, and respecting which there is still some obscurity, the name of andesine, "in consideration of the rock (from Marmato near Popayan) in which it was first recognised." Andesine (pseudo-albite in andesite) would be placed intermediately between labradorite and oligoclase: at the temperature of 15° Réaumur its specific gravity is 2·733; that of the andesite, in which the andesine was found, is 3·593. Gustav Rose, and subsequently Charles Deville (Études de Lithologie, p. 30), have doubted the independent existence of andesine as a species: as it rests only on a single analysis of Abich's, that made by Francis (Poggend. Ann. Bd. lii. 1841, S. 472), in the laboratory of Heinrich Rose, of the felspathic portion of a fine piece of diorite-porphyry which I brought from Pisoje near Popayan, indicating, indeed, great resemblance to the andesine from Marmato analysed by Abich, but yet the composition being different. There is still much greater uncertainty, as to the so-called andesine, in the syenite of the Vosges (from the Ballon de Servance and from Coravillers, analysed by Delesse). Compare G. Rose, in the already often-cited Zeitschrift

der deutschen geologischen Gesellschaft, Bd. i. for 1849, S. 369. It is not unimportant to recall here that the name of andesine is first adduced by Abich, as that of a simple mineral, in his comprehensive memoir entitled, "Beitrag zur Kenntniss des Feldspaths" (Poggend. Ann. Bd. l. S. 125 and 341; Bd. li. S. 519), in 1840, at least five years after the introduction of the word andesite, not antecedently to it, as has been sometimes erroneously stated. The formations in Chili, which Darwin so often calls "andesitic granite" and "andesitic porphyry," rich in albite (Geological Observations on South America, 1846, p. 174), may very well also contain oligoclase. Gustav Rose, whose memoir "Ueber die Nomenclatur der mit dem Grünsteine und Grünsteinporphyr verwandten Gebirgsarten" (in Poggend. Ann. Bd. xxxiv. S. 1—30) appeared in 1835, neither then nor subsequently used the word "andesite," the definition of which, according to our present knowledge of the nature of the ingredients, would be not "albite with hornblende," but, in the Cordilleras of South America, "oligoclase with augite." The already antiquated story of this term, which I have, I fear, treated at too much length, concurs with many other examples in showing that, in the course of the development of our physical knowledge, the descriptive sciences may gain by the stimulus to observation sometimes afforded by erroneous or inadequately grounded distinctions (as in the tendency to reckon varieties as species).

([610]) p. 436.—As early as 1840, Abich described oligoclase-trachytes from the summit-rock of Kasbegk, and from a part of Ararat (Abich, "Ueber die Natur und die Zusammensetzung der Vulkan-Bildungen, S. 46); also, as early as 1835, Gustav Rose (Poggend. Ann. Bd. xxxiv. S. 30) expressed himself cautiously to the effect: "that hitherto in his determinations he had not taken account of oligoclase and pericline, which yet are *probably* also components." The belief which was formerly much entertained, that a decided predominance of augite or of hornblende would also allow us to conclude as to a determinate species in the felspathic series,—glassy orthoclase (sanidine), labradorite, or oligoclase,—seems to be much shaken by a comparison of the Chimborazo- and Toluca-rocks, of the trachytes of the fourth and third divisions. In basaltic formations, hornblende and augite are often both equally abundant; that is by no means the case in trachytes; but, in a very few instances, I have found augite-crystals in Toluca-rock, and some crystals of hornblende in portions of the Chimborazo-, Pichincha-, Puracé-, and Teneriffe-rock. Olivines, which are so exceedingly rarely wanting in basalts, are as rarely to be found in trachytes as they are in phonolites; and yet we sometimes see, in particular lava-currents, olivines form in quantity by the side of augites. Mica is generally very unusual in basalt; and yet some basaltic summits of the Bohemian Mittelgebirge, first described by Reuss, Freiesleben, and myself, contain it in quantities. It is pro-

bable that the unusual sporadic occurrence of certain mineral bodies, and the reasons of their regular or normal specific association, are dependent on the concurrence of many not yet ascertained causes in respect of pressure, temperature, character and degree of fluidity, and rapidity of cooling. Specific differences of association are, however, of great importance in mixed rocks, as well as in dike- or vein-masses; and in geological descriptions drawn up in the open field, where it has been possible to do so with the described object actually present, care should be taken to distinguish whether any particular associated member is of general prevalence, or at least is rarely absent, or whether its occurrence is only occasional and apparently accidental. The diversity which is found in respect to the elements of a composite rock (*ex. gr.* trachyte) is also to be observed, as I have already remarked, in the occurrence of the rocks themselves. In both continents there are large territories in which trachytes and basalts, as it were, repel each other, as do basalts and phonolites; and other territories in which trachytes and basalts alternate in considerable proximity to each other. (Compare Jenzsch, Monographie der böhmischen Phonolithe, 1856, S. 1—7.)

([611]) p. 437. — Compare in Bischof, Chemische und physikalische Geologie, Bd. ii. 1851, S. 2288 and S. 2297; and Roth, Monographie des Vesuvs, 1857, S. 305.

([612]) p. 438. — Kosmos, Bd. iv. S. 365 (English edition, p. 320).

([613]) p. 438. — It is scarcely necessary to remind the reader that the expression "is wanting" only implies that a mineral species has hitherto been looked for in vain throughout a not inconsiderable portion of the volcanoes of an extensive territory. I distinguish between: wanting (*i. e.* not found); rarely found; and frequently present, but yet not normally and as a characteristic component.

([614]) p. 438. — Carl von Oeynhausen, Erkl. der geogn. Karte des Lacher Sees, 1847, S. 38.

([615]) p. 438. — See the Bergmännisches Journal von Köhler und Hofmann, 5th year, Bd. i. (1792) S. 244, 251, and 265. Basalt, rich in mica, as at the Gamayer Kuppe in the Bohemian Mittelgebirge, is a rarity. I visited this part of the Bohemian mountains in 1792, in company with Carl Freiesleben, who afterwards travelled with me in Switzerland, and who very materially influenced my geognostic and mining education. Bischof doubts mica being ever produced in a pyrogenous manner, and regards it as a product of metamorphic action "par la voie humide;" see his Lehrbuch der chem. und physikal. Geologie, Bd. ii. S. 1426 and 1439.

([616]) p. 438. — Jenzsch, Beiträge zur Kenntniss der Phonolithe, in the Zeitschrift der deutschen geologischen Gesellschaft, Bd. viii. 1856, S. 36.

([617]) p. 439. — Gustav Rose, Ueber die zur Granitgruppe gehörigen Gebirgsarten, in the above-mentioned Journal, Bd. i. 1849, S. 359.

([618]) p. 439. — The porphyries of Moran, Real del Monte, and Regla (the latter celebrated on account of the great silver riches of the Veta Biscayna, and the vicinity of the obsidians and pearl-stones of the Cerro del Jacal and Cerro de las Navajas) are, like almost all the metalliferous porphyries of America, entirely without quartz (on these phænomena, and some completely analogous ones in Hungary, see my Essai géognostique sur le Gisement des Roches, p. 179—188 and 190—193); but the porphyries of Acaguisotla, on the road from Acapulco to Chilpanzingo, as well as those of Villalpando to the north of Guanaxuato, which are traversed by auriferous veins, contain, together with sanidine, grains of brownish quartz. As at the Cerro de las Navajas, and in the basalt and pearl-stone-containing Valle de Santiago, along which one passes in going from Valladolid to the Volcano of Jorullo, the enclosures of grains of obsidian and glassy felspar in the volcanic rocks are, on the whole, rare, I was the more astonished when, between Capula and Pazcuaro, and especially near Yurisapundaro, I saw all the ant-hills filled with shining grains of obsidian and sanidine. This was in the month of September 1803. (Nivellement barométr. p. 327, No. 366; and Essai géognost. sur le Gisement des Roches, p. 356.) I wondered how it could be possible for such small insects to carry these minerals from a great distance. I have seen with lively pleasure that an ardent explorer, Jules Marcou, has met elsewhere with something quite similar. He says: — Il existe sur les hauts plateaux des Montagnes Rocheuses, surtout aux environs du Fort Défiance (à l'ouest du Mont Taylor), une espèce de fourmis qui, au lieu de se servir de fragmens de bois et de débris de végétaux pour élever son édifice, n'emploie que de petites pierres de la grosseur d'un grain de maïs. Son instinct la porte à choisir les fragmens de pierres les plus brillants; aussi la fourmilière est-elle souvent remplis de grenats transparents magnifiques et de grains de quarz très-limpides." (Jules Marcou, Résumé explicatif d'une Carte géogn. des Etats Unis, 1855, p. 3.)

In the present lavas of Vesuvius glassy felspar is very rare; not so in the older lavas (for example in those of the eruption of 1631), with leucite crystals. Sanidine is also found abundantly, without any leucite, in the Arso-current of Cremate, in Ischia, of the year 1301, which is not to be confounded with the more ancient one described by Strabo, which is near Montagnone and Rotaro. (Kosmos, Bd. iv. S. 340, Anm. 61, and S. 447; English edition, p. 260, Note 385, and p. 407.) Glassy felspar is not found in the trachytes of Cotopaxi, or the other volcanoes of the Andes: nor does it appear in the subterranean pumice-

stone quarries at the foot of the Cotopaxi. What have been formerly described in these as sanidine are crystals of oligoclase.

(619) p. 440.—Roth, Monographie des Vesuvs, S. 267 and 382.

(620) p. 440.—See above, Anm. 82; English edition, Note 606; Rose, Reise nach dem Ural, Bd. ii. S. 369; Bischof, Chem. und physik. Geologie, Bd. ii. S. 528—571.

(621) p. 441.—Gilbert's Annalen der Physik. Bd. vi. 1800, S. 53; Bischof, Geologie, Bd. ii. S. 2265—2303.

(622) p. 441.—The later lavas of Vesuvius do not contain any olivine any more than any glassy felspar; Roth, Mon. des Vesuvs, S. 139. The lava-stream of the Peak of Teneriffe of 1804, which has been described by Viera and Glas, is, according to Leopold von Buch, the only one which contains olivine. (Descr. des Iles Canaries, p. 207.) I have shown elsewhere (Examen critique de l'Histoire de la Géographie, t. iii. p. 143—146) that the statement that the eruption of 1704 was the first since the conquest of the islands at the end of the 15th century is erroneous. Columbus, in his first voyage of discovery, in the nights from the 21st to the 25th of August, when about paying a visit to Doña Beatriz de Bobadilla, in the Gran Canaria, saw the fiery eruption in Teneriffe. In his Journal, under the heading "Jueves 9 de Agosto," which comprises intelligence up to the 2nd of September, it is said, "Vieron salir gran fuego de la Sierra de la Isla de Tenerife, que es muy alta en gran manera;" Navarrete, Col. de los Viages de los Españoles, t. i. p. 5. The above-named lady is not to be confounded with Doña Beatriz Henriquez of Cordova, the mother of his illegitimate son (the learned Don Fernando Colon, his father's historian), whose pregnancy in the year 1488 contributed so materially to retain Columbus in Spain, and thus to occasion the New World to be discovered for Castille and Leon, and not for Portugal, France, or England. (Comp. my Exam. crit. t. iii. p. 350, 367.)

(623) p. 441.—Kosmos, Bd. iv. S. 276, English edition, p. 230.

(624) p. 441.—An important part of the rock-specimens collected by me during my American expeditions has been sent to the Spanish Mineralogical Cabinet, to the King of Etruria, to England, and to France. I do not refer to the geological and botanical collections possessed by my noble friend and fellow-labourer Bonpland, by the doubly sacred right of personal collection and discovery. Such a wide distribution of collected materials, when (by means of very precise notice of the localities in which each was found) the preservation of groups in geographical respects is not prevented, offers the advantage of facilitating the most varied and strict examination of the mineral species whose habitual association characterises the rocks.

([625]) p. 442.—Humboldt, Kleinere Schriften, Bd. i. S. 139.

([626]) p. 442.—The same, S. 202, and Kosmos, Bd. iv. S. 357, English edition, p. 312.

([627]) p. 442.—Humboldt, Kl. Schr. Bd. i. S. 344. I have also found much olivine in the "tezontle" of the Cerro de Axusco, in Mexico. Is this "tezontle" cellular lava or basaltic amygdaloid? The Mexican word tetzontli means stone-hair, from tetl, stone, and tzontli, hair.

([628]) p. 442.—Sartorius von Waltershausen, Physisch-geographische Skizze von Island, S. 64.

([629]) p. 442.—Berzelius, Sechster Jahresbericht, 1827, S. 392; Gustav Rose, in Poggend. Ann. Bd. xxxiv. 1835, S. 14; Kosmos, Bd. i. S. 464.

([630]) 4 42—Jenzsch, Phonolithe, 1856, S. 37; and Senft, in his important work, Classification der Felsarten, 1857, S. 187. Olivine is also found, according to Scacchi, in the calcareous blocks of the Somma, together with mica and augite. I call these remarkable masses emitted blocks, not lavas; the Somma has never poured forth any of the latter.

([631]) p. 442.—Poggend. Ann. Bd. xlix. 1840, S. 591, and Bd. lxxxiv. S. 302; Daubrée, in the Annales des Mines, 4ème Série, t. xix, 1851, p. 669.

([632]) p. 443.—Kosmos, Bd. i. S. 136, and Bd. iii. S. 615; English edition, vol. i. p. 121, and vol. iii. p. 444.

([633]) p. 443.—The same, Bd. i. S. 465. English edition, Note 293.

([634]) p. 443.—Humboldt, Voyage aux Régions Equinoxiales, t. i. p. 156—165. (Ed. in 4to.)

([635]) p. 444.—Compare Kosmos, Bd. iv. S. 365; English edition, p. 320.

([636]) p. 444.—Scacchi, Osservazioni critiche sulla maniera come fu sepellita l'antica Pompei, 1843, p. 10: against the view put forward by Carmine Lippi, and subsequently defended by Tondi, Tenore, Pilla, and Dufrénoy, that Pompeii and Herculaneum were overwhelmed and buried, not by rapilli and ashes ejected directly from the Somma, but through the agency of currents of water. Roth, Monogr. des Vesuvs, 1857, S. 458. (Kosmos, Bd. iv. S. 449; English edition, p. 409.)

([637]) p. 445.—Nivellement barométr. in Humboldt, Observ. Astron. vol. i. p. 305, No. 149.

([638]) p. 445.—Kosmos, Bd. iv. S. 367; English edition, p. 323.

([639]) p. 445.—On the pumice hill of Tollo, which is still two days' journey from the active volcano of Maypu, which latter never sent forth a morsel of such pumice, see Meyen, Reise um die Erde, Th. i. S. 338 and 358.

([640]) p. 445.—Pöppig, Reise in Chile und Peru, Bd. i. S. 426.

([641]) p. 445.—Compare Kosmos, Bd. iv. S. 417; English edition, p. 375.

(642) p. 445. — Franz Junghuhn, Java, Bd. ii. S. 388 and 592.

(643) p. 446. — Leopold von Buch in the Abhandl. der Akademie der Wiss. zu Berlin aus den J. 1812 — 1813 (Berlin, 1816), S. 128.

(644) p. 446. — Theophrastus de Lapidibus, § 14 and 15 (Opera ed. Schneider, t. i. 1818, p. 689, t. ii. p. 426, and t. iv. p. 551), says this of the Lipari-rock (Λιπαραῖος).

(645) p. 446. — Rammelsberg, in Poggend. Annalen, Bd. 80, 1850, S. 464, and Fourth Supplement to his Chemische Handwörterbuch, S. 169; compare also Bischof, Geologie, Bd. ii. S. 2224, 2232, and 2280.

(646) p. 447. — Kosmos, Bd. iv. S. 333, 354, 357—360, 366—368, and 377; English edition, p. 289, 310, 313—316, 322—324, and 332. Respecting particular cases in the geographical distribution of the pumices and obsidians in the tropical zone of the New Continent, compare Humboldt, Essai géognostique sur le Gisement des Roches dans les deux hémisphères 1823, p. 340—342, and 344—347.

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